Middle East Teachers of Science,
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'Making Connections'

Proceedings of the
Second Annual Conference for
Middle East Teachers of Science,
Mathematics and Computing

Edited by

Seán M. Stewart
The Petroleum Institute

Janet E. Olearski
The Petroleum Institute

Douglas Thompson
The Petroleum Institute

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Contents

Preface

These proceedings contain a selection of papers based on contributions presented at the Second Annual Conference for Middle East Teachers of Science, Mathematics and Computing (METSMaC 2006) which was held at the Beach Rotana Hotel & Towers, Abu Dhabi, between 14–16 March 2006. Submission of a manuscript for these proceedings was an option open to all presenters.

Given the scope of the audience a conference such as METSMaC intends to attract, umbrellaing as it does teachers at the upper secondary, pre-university foundation, and lower tertiary levels involved in the teaching of mathematics, physics, chemistry, biology, geosciences, and computing, the conference acts as a venue whereby connections between either traditionally separate subject areas, or common subject areas separated by the secondary–tertiary divide, can be forged and re-estiblished. Such was the intent that inspired this year's conference theme of *Making Connections*.

Taken together, the papers in this volume evoke themes of connectedness. Irrespective of the discipline area one will read time and again how teachers continue to struggle with making the learning process meaningful to those we teach, how teachers attempt to connect between the different backgrounds, cultures and abilities of our students, and how we as teachers try to connect between desired learning outcomes and assessment. Here many of the papers in their own way capture what it means if excellence in teaching and learning is to be achieved—we make connections.

The twenty-six papers making up this volume contain submissions from a wide range of teachers found teaching across a number of different countries including Brunei, Finland, Oman, Russia, Saudi Arabia, the United Arab Emirates, and the United States of America. As was done last year, these proceedings have been divided into two different parts. The first contains papers from the plenary and keynote speakers while the second contains contributed papers. The second part is further divided into four separate sections where papers are collated under headings of Mathematics, Science, Computing, and General for ease of identification.

Reflecting the growth and need for such a conference in the region, both the number of oral presentations and poster sessions grew compared to last year's inaugural conference. In additional to the five invited speakers who dilivered the opening plenary session and the four keynote sessions dispersed throughout the conference programme, there were forty-six oral and twenty-one posters contributed from presenters teaching not only within the Emirates, but from around the Gulf as well as from several countries further afield. The enlarged number of contributed papers made it possible to run six oral presentations per parallel session with all sessions able to cover each of the subject areas of mathematics, the sciences, computing, or general education. Over the course of the three days a total of 238 delegates attended, a number similar to last year's conference.

Invited speakers featured at the conference included Dr Jere Confrey, Plenary speaker from Washington University, United States of America; Dr Paul Ernest, Keynote Mathematics speaker from the University of Exeter, United Kingdom; Dr Marjan Zadnik, Keynote Science speaker from Curtin University of Technology, Australia; Mr Michael Aston, an information technology in education consultant from the United Kingdom who delivered the Keynote Computing talk; and Mr David Marsh, Keynote General speaker from the University of Jyväskylä, Finland.

The conference was held under the patronage of His Excellency Yousef Omair bin Yousef, Secretary General of the Supreme Petroleum Council, Chief Executive Officer of Abu Dhabi National Oil Company, and Chairman of the Governing Board for The Petroleum Institute, and was organised and hosted by The Petroleum Institute, Abu Dhabi. The generous financial support and sponsorship of the conference from our principal sponsors, The Petroleum Institute and Abu Dhabi National Oil Company (ADNOC), is also gratefully acknowledged.

Editors
Seán Stewart, Janet Olearski and Douglas Thompson

Plenary and Keynote Papers

From constructivism to modelling[‡]

Jere Confrey and Alan Maloney

Department of Education, Washington University, St. Louis, United States of America

Abstract

This paper traces the development of constructivism as a theory of epistemology and learning, and identifies ten key principles of this 'grand theory'. It identifies the need to further develop bridging theories that more closely link to empirical evidence. Within these bridging theories, it identifies primary themes: grounding in action, activity and tools, alternative perspectives, student reasoning patterns and developmental sequences, student-invented representations, socio-constructivist norms, etc., that are useful in linking theory and practice. Finally, it discusses how these ideas have been evolving into a view of modelling as an orientation to mathematics and science instruction, and identifies this approach as a successor to constructivist theories.

Introduction

In this paper we trace the origins and development of constructivism as a theory which has had a profound influence on mathematics and science education. It has been almost forty years since this theory entered the research field in mathematics and science education. Although at the current time, multiple theories (socio-cultural theory, social constructivism, cognitive science, and so on) as alternative approaches and offshoots have populated the field, it seems nonetheless timely and perhaps helpful to revisit the grand theory that catalysed a major portion of the research. Constructivism is a 'grand theory' in the typology offered by di Sessa and Cobb (2004), in that it was paradigmatic for mathematics education, though, grand theories are often 'too high-level to inform the vast majority of consequential decisions' (p. 80), at least at a level of specificity to guide instructional practice (also see Ernest (1991) and Thompson (2002)). To specify practice, constructivism relied on bridging instructional theories, such as 'Realistic Mathematics Education (RME)' (de Lange, 1987; Freudenthal, 1991; Gravemeijer, 1994)), 'didactical engineering' (Artigue, 1990; Balacheff, 1990), 'cognitively guided instruction' (Carpenter, Fennema, Franke, Levi and Empson, 1999) or 'constructionism' (Harel and Papert, 1991), all of which were compatible with the grand theory.

As a grand theory, constructivism served as a means of prying mathematics education from its identification with the formal structure of mathematics as the sole

[‡]Portions of this article have been summarised from a paper entitled 'A thirty year reflection on constructivism in mathematics education in PME', co-authored by Jere Confrey and Sibel Kazak, to be presented in Prague, July 2006.

guide to curricular scope and sequence. It created a means to examine mathematics from a new perspective – the eyes, mind, and hands of the child. Constructivism developed in mathematics education to counter the effects of behaviourism (Gagne, 1965; Thorndike, 1922), which had focused on measurement and the stimulus-based production of patterns and levels of outcomes. While behaviourism limited itself to theorising at the level of measurable and observable phenomena, hence its emphasis on stimuli and responses, constructivism was willing to engage in theorising about the constructs in students' minds and to link these to students' behaviour, patterns of responses and language use in relation to tasks. Constructivism evolved as researchers' interests in the child's reasoning grew beyond a simple diagnostic view of errors to understanding the richness of student strategy and approach. It took hold in practice because it addressed the two primary concerns of teachers: (i) students' weak conceptual understanding of over-developed procedures (relational versus instrumental in Skemp's (1978) language), and (ii) students' demonstrated difficulties with recall and transfer to new tasks. Constructivism did so by focusing the strengths and resources children brought to the tasks, and by making their active involvement and participation central to the theoretical framework.

However, what ultimately catalysed the development of the new theory was an application of evolutionary theory, as a theory of change and origin. The compelling influence of Piaget, as well as Vygotsky, with his development of socio-cultural theories, was the idea that knowledge evolved and changed, and that one could strive to describe the mechanisms of those changes, both in terms of the evolution of knowledge, discussed philosophically as epistemology and the history of ideas, and in terms of the individual over the course of his or her life. Constructivism is first and foremost a theory about how children's thinking changes over a variety of time scales, whether the time to solve an individual problem or a conceptual trajectory spanning years in its development, such as the concept of number. As Dewey acknowledged in *The Influence of Darwin on Philosophy* (McDermott, 1981),

> That the combination of the very words *origin* and *species* embodied an intellectual revolt and introduced a new intellectual temper is easily overlooked by the expert. The conceptions that had reigned in the philosophy of nature and knowledge for two thousand years, the conceptions that had become the familiar furniture of the mind, rested on the assumption of the superiority of the fixed and final; they rested upon treating change and origin as signs of defect and unreality. In laying hands upon the sacred ark of absolute permanency, in treating the forms that had been regarded as types of fixity and perfection as originating and passing away, the 'Origin of Species' introduced a mode of thinking that in the end was bound to transform the logic of knowledge, and hence the treatment of morals, politics, and religion (p. 32).

Many people still have difficulty accepting change and adaptation as a characteristic of mathematical knowledge, preferring to endorse a Platonic perspective. If so, they typically believe that while any local expression of mathematics may be tentative and subject to revision, they hold a kind of idealism about it that assumes enduring mathematics has a transcendent quality, beyond human constraint. We prefer to treat this

belief pattern as did Michael Polyani in *Personal knowledge* (1958), where he recognised the value in externalisation of a mathematical problem. He wrote,

> …true discovery is not a strictly logical performance, and accordingly, we may describe the obstacle to be overcome in solving a problem as a 'logical gap', and speak of the width of the logical gap as the measure of the ingenuity required for solving a problem…
>
> Since solving of mathematical problems is a heuristic act which leaps across a logical gap, any rules that can be laid down for its guidance can be but vague maxims…
>
> The simplest heuristic effort is to search for an object you have mislaid. When I look for my fountain pen I know what I expect to find, I can name it and describe it…
>
> Though the solution of a problem is something we have never met before, yet in the heuristic process it plays a part similar to the mislaid fountain pen or the forgotten name which we know quite well. We are looking for it as if it were there, pre-existent. Problems set to students are of course known to have a solution; but the belief that there exists a hidden solution which we may be able to find is essential also in envisaging and working at a never yet solved problem…
>
> A problem is an intellectual desire…and like every desire, it postulates the existence of something that can satisfy it; in the case of a problem, its satisfier is its solution. As all desire stimulates the imagination to dwell on the means of satisfying it, and is stirred up in its turn by the play of imagination it has fostered, so also by taking interest in a problem, we start speculating about its possible solution, and in doing so, become further engrossed in the problem. (pp. 125–127).

We often rely on this useful heuristic, and when writing a particularly difficult paper, we often consider it our task to 'get it right', knowing full well that (i) our view of what that means is our own and may prove compelling to others if we are fortunate, and (ii) *right* may change or be revised later when we revisit the idea in a different situation or moment in time. We therefore do not consider an 'idealistic' heuristic as contrary to constructivism, though others may disagree.

Ten principles of constructivism

In mathematics education, we trace constructivism's dominance to a watershed meeting in 1987 held as a part of the Psychology of Mathematics Education (PME) annual meeting in Montreal and focused on constructivism. Speakers there included Hermaine Sinclair, long time colleague of Piaget, Gerard Vergnaud, Jeremy Kilpatrick and David Wheeler. Though constructivism was the stated theme of the meeting, controversy raged as the plenary speakers alternately welcomed and spurned the theory. The major controversy seemed focused on statements by von Glasersfeld on radical constructivism summarising its two principles: (i) 'Knowledge is actively constructed by the cognising subject, not passively received from the environment', and (ii) 'Coming

to know is an adaptive process that organises one's experiential world; it does not discover an independent, pre-existing world outside the mind of the knower' (Kilpatrick, 1987). What caused a cleaving of the field was that von Glasersfeld labelled those holding only the first of the two beliefs as 'trivial constructivists' while those holding both as 'radical constructivists'.

His reasoning for doing so was premised on emphasising that the theory is about more than how one learns best, and entailed changes in one's fundamental epistemological commitments. Yet, on reflection, we would suggest that the polarisation at the conference was exacerbated by the listing of only two principles, obscuring essential distinctions of the theory. Hence, Confrey and Kazak (2006) wrote a paper unpacking the theory into ten principles. We describe these briefly here.

1. An *explanatory* model for development is necessary to guide educational practice. A descriptive model of cognitive stages is insufficient as it will only tell one what behaviours to look for, but not how to achieve them. An explanatory model is needed, identifying processes for change as well as likely paths of change over the course of learning.

2. Since evolution and adaptation provide a convincing model for conceptual-historical evolution of ideas (phylogeny), a strong candidate for articulating an explanatory model and underlying mechanism for development (ontogeny) is likely to reside in identifying parallel constructs. Thus, it would need to explain variation, similarity, change over time, and selection. *Genetic epistemology* is such a theory; it seeks to explain the ontogeny of intellectual development in terms of an individual's interactions, both social and environmental. It changes our focus from classical epistemology, in which we concentrate solely on the products of knowledge and their justification abbreviated in the phrase 'justified true belief' (or what we know and why we believe it). Instead, it focuses our attention on how we come to know it (processes) and how we communicate that knowledge with others (social interaction). This principle of constructivism does not require one to reject ontology, or an external reality or existence, but only to recognise and focus on our ongoing active participation, by means of tradition, practice, and physiology, in the process of knowing. Accepting that, as organisms, our ways of interacting shape what we claim as knowledge does not obligate one to reject the view that things independent of us shape those possibilities as well. The debate concerning the relationship between reality and knowledge still flourishes in some circles, especially concerning what comprises legitimate appeals for warrant and the meaning of truth. However, our treatment of constructivism emphasises the ideas of viability and fit (von Glasersfeld, 1982) rather than of permanent truth and assured objective properties. Unfortunately for constructivism, fallibilism in epistemology (Ernest, 1991) was mistaken for solipsism in ontology by many critics of constructivism. Rather, constructivism seeks to steer a course between positivism and solipsism. However, as stated by Larochelle and Bednarz (1998), 'Escaping the dictatorship of the object—the position of naive empirico-realism—only to come under the rule of the subject is not a particularly innovative solution' (p. 5). Genetic epistemology focuses our attention on creating an explanatory theory which elaborates 'a theory of the organism

who creates for him or herself a theory of the world' (von Glasersfeld, 1987 cited in Larochelle and Bednarz, (1998), p. 5). It concerns how and by what means an individual determines what theories of the world 'fit' his/her experience writ large (including social and environmental factors) rather than to what extent these theories 'match' an external reality. Hence, the stress is on epistemology. Emphasising adaptive fit requires a rejection of a correspondence theory of truth, which then needs to be replaced by alternative ways of linking human activity and the world to produce and explain forms of warranted knowledge. Two such approaches are described in principles 3 and 4.

3. Truth can be obtained in relation to a *coherence* theory of knowledge within the mathematical practice of building axiomatic systems, if it serves the role of establishing consistency within a limited system. That is, one accepts the 'truth' of statements that are derived deductively from axioms taken as starting points. While some may prefer to call it truth, others may prefer the term 'certainty' (von Glasersfeld, 1990) in recognition of the fact that even rules produce ambiguity and the need for further refinement of the terms, definitions, and scope of applicability. Coherence alone, however, is not sufficient as a lone explanation of truth because of the incompleteness of axiomatic systems to describe all of mathematics. Hence, even with coherence, one still needs to consider other sources of warrant. Furthermore, one will need to consider the balance of attention to be paid to these multiple sources of warrant and to how an understanding of coherence is developed.

4. In mathematics, warrant also derives from the careful development of conjecture, argument, and justification concerning the study of number, space, pattern, change, chance and data. We refer to these processes as *chains of reasoning*, which are the hallmark of mathematical thought. They include intuition, visualisation, generalisation, problem solving, symbolising, representing, demonstrating and proving, etc. In these areas, constructivism attends to how actions, observations, patterns, and informal experiences can be transformed into stronger and more predictive explanatory ideas through encounters with challenging tasks. These ideas, or concepts, can then become tools for building new concepts within each of these subfields. While deductive reasoning is certainly one important aspect (discussed along with coherence in principle 3), constructivism recognises the value of other forms of securing mathematical certainty, such as the coordination of representations, the identification of patterns, the recognition of similar ideas in apparently dissimilar settings (connections), the development and refinement of conjectures, and the applications of the ideas to other fields. This myriad of mathematical concepts and processes retains the connections to everyday experience, hence replacing the need for correspondence with the satisfaction of purposeful activity to resolve outstanding problematics.

5. We select the individual as the primary *unit of analysis* for assessing and evaluating cognitive achievements, to acknowledge the need to ensure that complete patterns of reasoning associated with key ideas are understood at the individual level, with associated coherence, adaptive fit and continuity. Akin to Steffe's

first-order models, this does not imply neglect of the ways in which those experiences are nested and shaped within patterns of participation in larger collective membership units (dyads, classes etc.). Further, it is a practical decision based on typical schooling, which treats students as individuals as they move across grades and locations, at the level of assignment, in relation to future studies and work, and in relation to typical accountability systems. We recognise the importance and viability of including other units of analysis, such as dyads, groups, classes, schools, etc., as a second-order model in relation to the assessment of an individual's developmental path. The distinction between first- and second-order models will prove useful to the observer and researcher, but should not lead one to assume that the individual student experiences them as distinct or separate. We liken this decision to place the individual as the first-order model to Vygotsky's choice of the word as the fundamental unit of analysis. This choice did not preclude his theorising about sentences or complex social interactions, but it guided his empirical designs and permitted him to identify the building blocks of his theory. Similarly, constructivist scholars investigate collective social interactions, purposes and forms of engagement, and coordinate these with students' interactions with various physical devices and tools. However, our claim is that collective social interactions should be linked with their effects on individual student's intellectual growth. This should not be construed to mean that personal identities are considered only as individually constituted, nor does it imply that membership in multiple groups is neglected or ignored.

6. To explain sources of *variation for individuals* and avoid a standardised or uniform theory of knowledge, one needs to consider three broad and interacting factors: the individual's current state of development, social and cultural influence as a member of a tribe (group), and environmental/physical factors in relation to the task at hand. Though evolutionary theory regards mutation as the primary source of variation, we ascribe unique arrangements of the three interacting factors as the means of producing the essential diversity that spawns invention and serves as a source of variation. One of the most compelling contributions of constructivism is the documentation of rich and interesting ways that children express ideas. We see it in the form of inventive representations, language, forms of reasoning, alternative pathways, and explanations. Many of these expressions are regularly overlooked in traditional classrooms. This can result in missed opportunities for interesting connections among ideas, undermine children's confidence in their own emerging reasoning, and result in proposals which, though supporting alternative paths, are instead labelled as erroneous.

7. To explain *selection*, one must consider how the same three forces act to define criteria for viability for cognitive ideas, (as 'mortality' vesus 'survival', itself a far oversimplified view of natural selection, would not serve this purpose). First, we point out that selection depends on processes of change and adaptation. We propose that pragmatism, in relation to functional fitness, provides the means for this – that a difference is viable when it makes a difference (James, 1907). This conception then invites one to propose sets of processes that instigate, regulate, and evaluate change in terms of functional fitness. For Piaget, these were assim-

ilation and accommodation. For Dewey, it was the process of inquiry, wherein the indeterminate situation is transformed to a determinate situation. Peirce emphasised the importance of doubt in securing deep understanding (see Peirce, 1877, 1878). In constructivism, compatible with both of these philosophers, cognitive change or intellectual growth begins with a perturbation, or a problematic, which is a perceived roadblock to where one wants to be (Confrey, 1991). It is followed by an action, to attempt to eliminate that perturbation or to satisfy the felt-disequilibration. As emphasised in Sinclair (1987), the action of the individual is key in that the degree of active participation often determines the success of the action in resolving the problematic. As Sinclair emphasized, that action often involves comparison or transformation of the original situation. In most school-related settings, as well as many others, a representation is produced to record, signify, or communicate the results of that action. This leads to and supports an act of reflection, to assess whether the original perturbation or felt-need was satisfied, or whether more action is required. The cycle repeats, continuing to transform the problematic towards resolution. This *cycle of constructive activity* represents the activity of selection for viability of ideas. In all steps, to varying degrees, the influence of social and environmental factors are at play – sometimes with more or less emphasis on one or the other. Summarising this process, Larochelle and Bednarz (1998) wrote,

> Drawing on a range of fields including second order cybernetics and contemporary linguistics and epistemology, constructivism centres of the development of a 'rational' model of cognitive activity of either an individual or collective variety, including the narratives which are devised to give shape and meaning to our actions... Or, to take Korzbsky's metaphor, a map can never be said to 'be' the territory – all the more so in that the territory is a question of representation as well. What the map 'refers to' is inevitably an affair of not only the particularities decided on by its maker but also the distinctions he or she chooses to make in accordance with his or her project and the success with which his or her cognitive and deliberative experiences have met (p. 6).

8. In the learning process, there is an unavoidable element of *recursiveness*. One recognises multiple forms of awareness of oneself as a learner, as one: (i) determines if the goal, purpose or problematic has been satisfied; (ii) creates records and representations to communicate with others and/or to assist in reflection and evaluation, and (iii) remembers successful and viable methods for future use (schemes). In addition, in the description of learning, the levels of recursiveness accumulate further. As stated by von Foerster (1984) , 'it takes a brain to write a theory of the brain; now, for this theory to be complete, it should also be able to explain the fact of its own elaboration, and what is more, the writer of this theory ought to be able to account for his or her writing' (p. 11). Properties of the observer must be part of the description of what is observed (Larochelle and Bednarz, 1998). That is, our explanations must serve to both describe what we observe and to explain our own experience, at the level of mechanism. It is this

recursiveness that produces in humans the particular ability to abstract, a key element of mathematics.

9. Because the focus in constructivism is on genetic epistemology, *objectivity* must be redefined as the result of a consensus among a group of qualified individuals to authorise a particular description or explanation as viable and as shared among them. According to the standards of any particular set of knowledge games (discipline), the standards for authorising knowledge differ; as a theory about functional fitness, objectivity represents a perceived stability in ideas, not a permanent state of being. This is more akin to intersubjectivity as discussed by Thompson (2002). It can be a case of a symmetric assumed tacit understanding by all parties, as in Cobb's 'taken-as-shared' (Cobb, Yackel and Wood, 1990), or a case of a stated and negotiated understanding or asymmetric but uncontested recognised difference by one or more parties, as in Confrey's 'agreeing to agree' (Confrey, 1995). How these bear upon and are used in the development of an individual's independent reasoning in mathematics or science is a source of valuable investigation, and has led to the development of socio-constructivism as a distinct subset of constructivism. Within such an approach, one can examine the development of 'knowledge communities' as a larger unit of analysis, provided it is connected to its effects on independent reasoning patterns for individual students, as a parallel target unit of analysis.

10. An understanding of the first ideas will lead people to more viable and effective models of knowledge and will engender more productive knowledge acts as one recognises the observer–observed interactions not as limitations but as accomplishments and agreements, and not simply received knowledge, but as active choices and selections by reflective knowers or *consciousness*. This treatment of consciousness should be a primary outcome of learning in mathematics or science. Désautels (1998) recognised the need for a broader level of awareness than what is obtained by reflective abstraction in terms of understanding by jumping to a recognition of how these chains of reasoning are embedded in a larger framework of knowledge construction and debate:

    > ... one is quite justified in thinking that ignorance of the relative, discontinuous, and historically located character of the development of scientific knowledge (Serres, 1989) will leave this student quite unprepared to gauge the limits of this type of knowledge and to appreciate the real worth of other knowledge forms and knowledge games (p. 124).
    >
    > Whence the necessity, if one wishes to participate in the conversation of scientists, of understanding how the latter impart meaning to the notions and concepts they use; whence also the importance of epistemological reflexivity. Only when knowing subjects become aware of the postulates which underlie their usual ways of knowing, and when they place their own knowledge, they will become able to open themselves to other potentialities. Although the intellectual process of reflexivity is often associated with metacognition, it is distinct from the

> latter in that it does not involve the intellectual operations or strategies in developing this or that bit of knowledge. Instead, reflexivity draws attention to 'that which goes without saying', that is, the unspoken assumptions or the un-reflected aspects of thought which lead one to be referred to metaphorically as the blind spot of a conceptual structure which is a condition necessary for beginning that process whereby thought is complexified and autonomized (Varela, 1988) (p. 128).

Enduring legacies

Constructivism as a 'grand theory' requires interpretive or bridging theories to link it to practice. Through careful work in collaboration with practitioners, researchers have identified a set of common approaches to tasks and classroom activities that promote the kind of learning implied by the theory. Many of these legacies are in practice in innumerable classrooms today. However, one challenge confronting constructivism's usefulness in student learning in practice is that too often these legacies are cast by themselves as the theory itself. As a result, we often see teachers practice (ineffectively) the trappings of constructivism with little understanding of the grand theory and with far less success in promoting student conceptual growth as a result. It is important to recognise that the grand theory acts as the glue to hold the legacies together. These major legacies are:

Grounding in action, activity, and tools. This element, common to most of the constructivist initiatives in mathematics, came from the claim that mathematical ideas are fundamentally rooted in action and situated in activity.

Alternative perspectives, student reasoning patterns, and developmental sequences. One characteristic of constructivism is adaptation as a mechanism to explain the transformation of human thinking over time. This has led mathematics educators to identify critical moments in learning when an earlier way of thinking fails to account sufficiently for new ideas and an invention is needed to account for those examples, extensions, or phenomena (Nakahara, 1997). A number of these ideas are found in mathematics; perhaps the best known is the early conception that 'multiplication makes bigger, division makes smaller'. Researchers recognised that extending multiplication and division to these values must be accompanied by directly encountering this conflict in expectations. Such encountering is not simply a matter of seeing the result, but often of re-examining one's underlying models. For instance, if multiplication is based in arrays, then multiplication by a fractional part will require a transition to area models. Further, if the problem of $a \times b$ for $a > 1$ and $0 < b < 1$ is managed by using commutativity and repeated addition of the fractional unit, the next case where both $0 < a < 1$ and $0 < b < 1$ must still be managed instructionally. As this research evolved, we learnt that even when the issue is 'resolved' for multiplying fractions such $a/b \times c/d$, it resurfaces when students are faced with multiplying decimals, such as 3.45×0.56. Greer (1987) faced this when he examined student predictions of the required operation and asked students to calculate the prices of different volumes of petrol. When the numbers were obscured, students typically predicted the need for multiplication; when the numbers were revealed, and one of the numbers was a decimal less than one, they usu-

ally switched to division as the predicted operation. Greer argued that students should not be inclined to change their predictions if they possessed what he labelled 'conservation of number' (Greer, 1987). This research tradition suggested that certain beliefs of children develop in limited settings, and that extending them in ways that conflict with those original predictions not only provides them with the new procedures, but get them to think through why there is a need to revise their ideas.

Student-invented representations and multiple representations. Another shift that accrued due to the constructivist research programme was in the exploration of role of representations in mathematics. These had constructivist roots in that they were used as evidence of students' active participation and their ability to compare and transform their basic ideas, building more and more abstract ones. With younger students, researchers explored the ways in which children would build their own representations of ideas with increasing sophistication. At the more advanced levels of mathematics, the focus was on the use of multiple representations. Instead of assigning the greatest prestige to the most symbolic of representations, researchers discovered that different representations afforded students differing insights into the mathematical ideas (Artigue, 1992; Confrey and Smith, 1989; Dreyfus, 1993; Janvier, 1987; Kaput, 1987).

Socio-constructivist norms. These were produced as researchers took constructivism into the classroom. As stated in the principles, in order to participate successfully in a constructivist environment, classrooms must shift from a passive to an active role. Some explored how these shifts disrupted normal assumptions under the 'didactical contract' (Brousseau, 1984; Chevallard, 1988), and discussed the need for changing the students' expectations. Cobb, Yackel and Wood (1990) found that they needed to shift the behaviours of the students as early as first to third class, to encourage them to listen to other students and to talk about their solutions (diSessa and Cobb, 2004). Drawing on the work of Bauersfeld (1998) and Voigt (1985) and symbolic interactionism, Cobb and his colleagues established that if a teacher were to successfully develop a constructivist orientation among students, s/he would need to 'renegotiate classroom social norms'. For example, they explain that constructivist classrooms tend to count as 'different' those solutions that while producing the same result, represent different cognitive processes. This shift in what is seen as different changes what is learnt in two ways: (i) different ideas are brought to the foreground, and (ii) students' reflections on their own thinking are strengthened. Finally, teachers learning from students is often reported.

New Topics. The introduction of the technological learning environments in various topics in a school mathematics curriculum, such as geometry and statistics, provided new insights into how students learn these topics and how we teach them.

Assessment. Constructivism also opened the topic of assessment. Assessment came to be viewed as a means to support constructivist practices in a variety of ways. First, concerns surfaced that the traditional testing approaches failed to evaluate students' knowledge sufficiently, due to their focus on multiple-choice format or sole emphasis on the production of answers. Secondly, assessments were viewed as key contributors to students' awareness of their own learning and to increasing their ability in reflective abstraction (Bell, Swan, Onslow, Pratt, Purby and others, 1985; Simon, Tzur, Heinz and Kinzel, 2004). Thirdly, researchers focused on using richer tasks to give teachers increased understanding of student reasoning as a means to support constructivist

curricular changes and to strengthen teachers' diagnostic teaching (Schoenfeld, 1998).

Teaching and teacher education. Constructivist theory has had a dramatic effect on teacher education. A number of researchers have been engaged in developing pedagogical frameworks that focus on the designing of tasks, planning of lessons, stimulating, guiding, and supporting of student discourse and activities, creating a learning environment, and analysing and assessing student work and progress. Brousseau's work on the didactical contract and how to devise tasks that lead students to take responsibility for the problem (Brousseau, 1984; Brousseau, 1997), devolution being one such example (Balacheff, 1990). Douady (1986) discussed how this becomes 'situations for institutionalisation'.

This initial work on teaching has been complemented by a recognition that teachers need to both learn about constructivist learning, and to experience mathematics from a constructivist perspective. Researchers in PME have conducted studies of teacher education (Ball, 1993; Bauersfeld, 1995; Jaworski, 1991; Ma, 1999; Simon, 1988) and at least three volumes of these studies have been dedicated to such issues (Ellerton, 1999; Jaworski, Wood and Dawson, 1999; Zack, Mousley and Breen, 1997). In most cases, they have determined that teachers need time to both engage with the material as learners within a constructivist paradigm and to consider what this implies for their practice. At the current time, there is particular interest in three arenas: how to describe the nature of teachers' knowledge as illustrated by *'profound understanding of fundamental mathematics'*, (Ma, 1999), in Ball's current characterisations of teacher knowledge (Bass and Ball, 2005), and in *'Lesson Study'*, the Japanese professional development process (Yoshida, 1999).

Methodology. Over the course of the past thirty years, there has been a number of developments in the methods of conducting research. Piaget was the inventor of the 'clinical method' (Piaget, 1976), the clinical interview now being replaced by teaching experiments (Cobb, 2000; Confrey and Lachance, 2000; Lesh and Kelly, 2000; Simon, 2000).

Constructivism and modelling

We predict, with others, that research on modelling in mathematics represents a key bridge and is likely to be one rightful successor to constructivism (Confrey and Maloney, in press; Gravemeijer and Stephan, 2002; Lehrer and Pritchard, 2002; Lesh and Doerr, 2003). Within such a perspective, one views knowledge construction as the mapping of and exploration of the systematicity of relations between a base and a target domain. The reason we make a claim of succession is epistemological: modelling can address the dual challenges of providing a focus on coherence views of truth, while replacing the correspondence theory with a viable alternative. Correspondence is cast as the relationship between two domains of understanding, one secure and the other more uncertain, rather than between an individual and an external reality. However, those two domains can be of varied levels of abstraction.

In our research group, we have found it useful to draw upon Dewey's definition of inquiry:

> …the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations

> as to convert the elements of the original situation into a unified whole (Dewey, 1938, cited in McDermott, 1981, p. 226)

We have used this description as a starting point to create a definition of modelling:

> *...modelling is the process of encountering an indeterminate situation, problematizing it, and bringing inquiry, reasoning, and mathematical structures to bear to transform the situation. The modelling produces an outcome – a model – which is a description or a representation of the situation, drawn from the mathematical disciplines, in relation to the person's experience, which itself has changed through the modelling process.* (Confrey and Maloney, in press)

Moreover, one can compare and contrast a variety of types of models, and hence produce a more nuanced continuum for guiding students' mathematical development. Lehrer and Schauble (2000) provided a four-part taxonomy of modelling designed to progress from literal resemblance to relational structure: physical microcosms (e.g. a physical model of, for example, an elbow), representational systems (e.g. a map), syntactical models (e.g. modelling phenomena as a coin toss) and hypothetical-deductive models (e.g. modelling gas kinetics as collisions of billiard balls). At one end of the spectrum, children are confronted with the challenge of understanding how the source of mathematical ideas can be rooted in physical settings. As students move increasingly towards the hypothetical-deductive models, one expects significant use of coherence as a means of deciphering relationships and producing predictions beyond direct physical correspondences, obtaining the mathematics of axiomatic systems. Representational systems begin to reveal the potential insights obtained by comparing and contrasting multiple representations, in which consistency is sought, while differences are used to highlight new features and assist in establishing warrant for various conjectures. Across the spectrum, Lehrer and Schauble (2000) emphasise the mathematical underpinnings of the effort in the acts of quantification, the creation of measure, the understanding of data and probability, and/or the development of a spatial form of reference. A modelling approach brings together mathematics with other disciplines, while also reserving significant time for developing its internal relations and meanings. Much more work remains on how the development of model-based reasoning emerges, but we see significant promise in this area as the epistemological successor to constructivist epistemology.

An example

In this last section of the paper, we plan to work through an example that draws upon both mathematics and science, out of respect for our interdisciplinary roots. The example is on radioactivity.

Recently, we have read biographies of Marie Curie by Sarah Dry (2003), called simply *Curie*, and Barbara Goldsmith (2005), entitled *Obsessive genius: The inner world of Marie Curie*. The authors explore Marie Curie's contribution to science. Goldsmith cites Spencer Weart, director for the Maryland Center for History of Physics who described Curie's contribution as follows:

> The properties of a metal, for example, include its silvery shine, its brittleness, its heat conductivity and capacity (It feels cold when you touch it, etc.). None of these are the properties of a single atom such as iron. Realising that radioactivity could not be changed by any chemical procedure – dissolving in acid or water, heating or cooling, etc. – and therefore it was an atomic property was Marie Curie's important intellectual contribution to science (Of course, we now realise radioactivity is a property of the nucleus, and not the entire atom). (Goldsmith, 2005, p. 78)

Let us unpack this statement in relation to constructivism and modelling. First of all, some contributions to science are considered revolutionary, rather than normal, science. Normal science, extends existing knowledge to new instances, tools, etc., while revolutionary science transforms the fundamental concepts of a subfield (Kuhn, 1962). They change how we think about the world. Marie Curie's contribution was revolutionary in this sense, if one considers what was accomplished from the perspective of the time period, not merely as another fact to be added to one's store of terms and definitions. Describing radioactivity involved the identification and measurement of radiation, surmounted by the realisation that its behaviour is a kind of signature for an element. Curie did not discover radioactivity as a phenomenon, rather she created a means to explain and identify elements, and subsequently used this to identify two new elements. One reason we like the term 'modelling', is that it permits one to steer a course between discovery and invention – 'modelling' acknowledges that one is trying to understand phenomena and events, and in doing so, creating a lens with which we can explain and predict.

Novices go through a process of building more and more adequate models of the world. History can be a tremendous resource in trying to understand student models, as it provides a real time example of how ideas evolve. And while, practically, we may not expect our students to recapitulate history, history does provide us with the basis for excellent thought experiments. To help students be successful at the process of repeated reinterpretation, however, we as their teachers must rethink our own content in terms of genetic epistemology. That is, we must simultaneously undertake two efforts. Firstly, we must wrest our own knowledge of the content from the teaching most of us received, and reconstruct it in a pragmatic, evolving sense. What does it permit us to do? What problem does it solve. Why might someone have thought of it? What alternatives were there? Secondly, we must learn to listen closely to our students to understand their voices and ideas, which may contain vestiges of ours, in words or references, but may nonetheless be quite different, rather than simply incomplete. To illustrate this further with the example of radioactivity, we continue with more of the history.

Wilhelm Röntgen had discovered and named X-rays (1895–96), which could pass through opaque surfaces and illuminate objects on the other side of them. This was by itself a wondrous accomplishment, validated in the award of the inaugural Nobel Prize in physics to Röntgen in 1901. But, as the presenter of his Prize noted, 'The actual constitution of this radiation of energy is still unknown' (Goldsmith, 2005, p. 65). (Note that radiation differs in meaning here from radioactivity). A short time after Róntgen's discoveries, Henri Becquerel sought to explore a possible link between phosphorescence and X-rays. Fluorescence, phosphorescence and X-rays all depending on external sources of energy to emit the mysterious rays that exposed photographic

plates, though phosphorescent materials continue to emit rays after the external source is removed. Becquerel was experimenting with uranium salts, assuming that the sun was required as the external source for uranium's phosphorescence. One cloudy day, he prepared an experiment but stowed a photographic plate and uranium salts to await a sunny day on which to conduct the phosphorescence experiment. He later found that even without the sun, the uranium salts had by themselves emitted some kind of rays and produced strong images on the photographic plate. Naming these 'Becquerel rays', he presented six papers on the phenomenon in 1897, and then abandoned the studies. But it was this phenomenon to which Marie Curie decided to devote her doctoral thesis at the Sorbonne. She studied the uranic rays, working out a way to measure their relative strength, using an electrometer (previously developed by her husband Pierre Curie) and a piezoelectric quartz crystal, to detect minute electric currents that resulted from ionisation of air by uranium and its compounds. With Pierre, she devised a way to measure tiny currents resulting from Becquerel rays. The work, extraordinarily precise, tedious, and physically demanding, resulted in 'discovering [previously undescribed] elements by measuring their radioactivity, thereby throwing open the door to atomic science' (Goldsmith, 2005, p. 76).

Marie Curie's research had done far more than to contribute to the store of scientific facts. She had (i) selected a reproducible phenomenon and decided to study it more closely, (ii) found a consistent, reliable and valid way to measure it, (iii) explored variation of the phenomenon, (a) in terms of a variety of substances and compounds that could produce it (settling on pure uranium as a standard), and (b) in terms of the conditions and of the source materials' form of matter (solid, liquid, gas) (and documented invariance in the behaviour of the radioactive emissions regardless of temperature and state of matter), and (iv) recognised that the radioactive behaviour was a property of the atom itself rather than a property of material, and thus did not vary across physical states of matter. It was this combination of scientific insights which led to a Nobel Prize for this work in 1903, and which led to her discovery of two new elements, polonium and radium.

It is also striking to note that Marie Curie was nearly denied credit for this contribution, when, in 1903, only Pierre Curie and Henri Becquerel were sent an official Nobel Prize notification letter. Further, there is speculation that Becquerel, a wealthy member of the French scientific elite, had influenced this omission to gain further credit for himself. Only when Pierre pledged to refuse the honour was Marie's name added to the Nobel citation.

While the Curies continued to study one of the substances in depth, confirming their discovery of a new element (radium) through the use of the new technique of spectroscopy (Dry, 2003), she and Pierre rejected the idea that radioactivity emanated from within the atom. It was Rutherford and his colleague Soddy who took the perspective that radioactivity did not emanate from forces outside the atom, but from inside the atom, and they showed that through radioactive emission an element is 'transmuted' into another substance, at a constant rate. By studying thorium-X (an isotope of radium) whose half-life was approximately four days, they were able to show that transmutation was not simply some obscure and spurious form of alchemy but rather that it is a stable property of particular elements.

We tell this story, perhaps familiar to many, as an example to build on about the idea

of genetic epistemology and to introduce why we suggest that modelling provides a powerful bridge with which to link mathematics and science. This (condensed) history of radioactivity is an example of genetic epistemology, sorting out how the discovery was made as a series of investigations. X-rays were the first form of radiation shown to pass through objects, and raised the question of how to make sense out of the broader phenomenon of radiation. The extension to fluorescence and phosphorescence raised the question of the link between these emanations and outside sources. A key question was what it would mean not to have an outside source, if the atom itself, the smallest unit of chemistry and physics, were the source of the emanations. Finally, once the phenomenon of radiation from uranium was established, there was the work of creating a way to measure it, what variations to consider, and how the shift was made to the view of radioactivity as a property of atoms. The final step – viewing radioactivity as the decay of some of the matter in the atom, with an invariant half-life, completed this part of the evolution of ideas. Few of us were introduced to radioactivity in this manner.

Secondly, though Curie would not have described her work as modelling, we find this characterisation useful in order to capture the view that she did far more than document an unknown phenomenon. Rather she created a way of looking at materials in a different manner. That has led to carbon dating, medical and scientific visualisation technologies, medical therapies, countless scientific experimental techniques, repeated revision of our view of the evolution of the cosmos, and the unbelievably precise measurement of time itself. Rutherford's subsequent work on the structure of the atom itself is a clear example of modelling in a traditional sense. We would classify the Curies' work as modelling as well. Using our previous definition, we would describe Marie and Pierre Curie's contribution of radioactivity as an example of how an indeterminate situation can be transformed to a determinate one through a process of inquiry and reasoning on an existing problematic. Hence, it is an act of modelling.

We now contrast this with the presentation of radioactivity in secondary school textbooks in the United States, both in science and in mathematics. In science, a high school textbook reports the discovery as follows in a chapter called Nuclear Chemistry:

> 'In 1896, the French chemist, Becquerel made an accidental discovery. He was studying the ability of uranium salts that had been exposed to sunlight to fog photographic film plates. During bad weather, Becquerel could not expose the sample to sunlight, but happened to leave it on top of a photographic plate. When he developed the plates, he discovered that the uranium salt still fogged the plate. At that time, two of Becquerel's associates were Marie Curie (1867–1934) and Pierre Curie (1859–1906). The Curies were able to show that rays emitted by the uranium atoms caused the fogging of the plates. Marie Curie named the process by which materials give off such rays **radioactivity**. The penetrating rays and particles emitted by a radioactive source are called radiation'. [Wilbraham, Staley, Matta and Waterman, 2005]

The text presents correct definitions at a subatomic level; we see that a formal and highly procedural account for scientific accomplishment is preserved and communicated. However, one notes that no reference in this text is made to the discovery of X-rays nor to the prior uses of the term radiation. Becquerel's experiment is not linked

to fluorescence or phosphorescence, and hence the selection of uranium salts is not grounded in any context. The challenge of measurement is ignored, along with the variations of the experiments conducted by the Curies, and Marie Curie is credited most directly with simply naming the phenomenon. Rutherford and the development of a nuclear or subatomic explanation are ignored. The entire revolutionary intellectual ferment of the time period and its subsequent import to all kinds of modern technologies and medicines are poorly grounded.

In mathematics textbooks, the typical approach is to provide a formula for radioactive decay as an example of the application of an exponential function. The formula is nearly always written with a base of e and the student is asked to either find the constant k or use a given constant to predict the length of a half-life. Unfortunately, exploration of the discovery or study of the phenomenon itself, so as to ground what is in effect a mathematical model, relative to the physical antecedent of the model, is minimal or lacking in most mathematics textbooks.

Contrast this mathematical treatment with the following simulation, which we use to complement a discussion of the scientific mechanism. We introduce this simulation here to illustrate a number of other features of the constructivist approach including hands-on, minds-on use of materials, the role of multiple representations, possible uses of technology and an example of alternative conceptions.

We provide students with pairs of dice and a chart representing thirty atoms. The dice are a proxy for simulating the probability of atomic radioactive decay. For each atom during each discrete time period, the students roll the dice; if the sum of the values on the dice is less than four, they record that the particular atom decays. They roll the dice once for each surviving atom in each time period (see Figure 1).

Some students rearrange the data, placing all the atoms that decayed in the first time period together (and implicitly re-numbering the nuclei in the process), to produce a chart of the number of atoms decaying in each time period. The result is, essentially, a set of horizontal bars that displays the number still surviving after each time period. (see Figure 2).

	Nucleus →																														
time period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total surviving this period
0																															
1					X																			X							
2													X																		
3																															
4																			X										X		
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11										X										X											
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15	X																					X									

Figure 1: Chart of one student's results in radioactive simulation. Each time period is represented by a roll of the dice for each of the 'atoms' surviving at the beginning of the time period. The **X**'s indicate which 'atom' decayed due to a roll of three or less in the indicated time period.

time period	Nucleus → 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total surviving this period
0																															
1																													X	X	
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15						X	X																								

Figure 2: Data in the chart presented in Figure 1 reorganised to visualise the number of surviving atoms at each time period. However, the **X**'s now indicate each atom that decayed during a time period, but arranged so that the length of open cells in each row represent the number of surviving (undecayed) at the end of that time period.

Then the students accumulate these data to produce class totals. Up to this point, this is a very simple simulation in which the mechanism, a dice roll with a probability of decay, has been applied repeatedly. The class data are reordered in a table, in order from atoms which decay most quickly (i.e., decay after the fewest dice rolls) to those which persist the longest (Table 1). Transferring these data to the coordinate plane produces a graph of the number of the number of non-decayed atoms as a function of the number of dice rolls emerging from the chart and table (Figure 3).

n	C	®C
No. of dice rolled	Surviving nuclei	Ratio
0	180	1.00
1	164	0.91
2	146	0.89
3	137	0.94
4	121	0.88
5	116	0.96
6	104	0.90
7	94	0.90
8	85	0.90
9	77	0.91
10	69	0.90
11	63	0.91
12	57	0.90
13	51	0.89
14	45	0.88
15	38	0.84

Table 1: Pooled class simulation data in table. The right column contains ratios of the second column's entries.

In terms of multiple representations, it is useful first for students to become adept at coordinating the table and the graph to see the exponential in two forms. In the graph, one learns to 'see' that each new bar is approximately the same proportion of the previous bar, hence indicating a function in which the amount of remaining radioactive material is always the same proportion of the previous amount. Then, we found it useful to help students learn to look at the table for this same coefficient of proportionality (which, in this situation, is a probability). Students are accustomed to looking for differences first, especially in linear and quadratic equations, but less accustomed to looking for constant ratios in tabular form. We invented a symbol in our software to support this type of analysis ('®', see Figure 3).

Finally, there is the challenge of writing an equation to fit the data. We assume that students have undertaken prior work using either a doubling or a halving function. Thus, in exponential growth for the form $y = 2^x$, the student has already experienced a new concept of rate – what Confrey has labelled in previous work as 'multiplicative rate' (y_2/y_1 per unit time; Confrey and Smith, 1994). This concept of rate contradicts

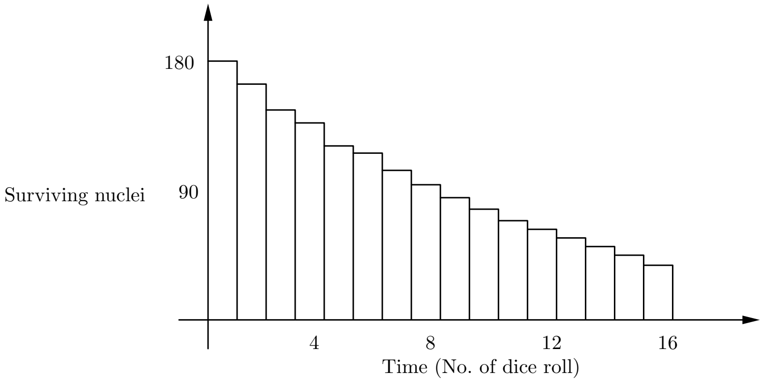

Figure 3: Function probe bar graph of pooled class simulation data.

most students' concept of rate ($y_2 - y_1$ per unit time). That is, as can be seen in the graph, the rate of the decrease of surviving nuclei is not constant as in a linear function, but constant in a multiplicative way.

In this simulation, then, the student must adapt that understanding to the change in probability associated with the values of the dice rolls. (An alternate example of experimenting with probability is to use a cup with *M & M's*, which have the letter *M* on one side, and then add or subtract *M & M's* based on the number showing *M*). Then, the student must be able to recognise that the dice values less than four: (1,1), (1,2) and (2,1); constitute 3 out of the total of 36 possibilities, or 1/12th, making 11/12 the likelihood of survival of a nucleus. This is applied to their initial amount to produce the equation $P_t = P_0(\frac{11}{12})^t$. The probability coefficient in this model comprises another concept of rate.

One can subsequently discuss how to change to the formula $P_t = P_0\mathrm{e}^{-kt}$. Recall that the k in this equation (similar to the r in the compound interest formula $P_t = P_0\mathrm{e}^{rt}$) is yet another form of rate. The movement to the continuous instead of the discrete case is also challenging, and beyond the scope of this paper, though we have developed some approaches to it.

To summarise, conceptually, we have identified four distinct concepts of rate: $\Delta p/t$, p/t (the ratio p per unit time), probability p per unit time, and k as a rate in the continuous rather discrete case. Seldom are students carefully introduced to these distinctions, and as a result, the concept of rate for most students is over-generalised and poorly understood.

Once students have explored the three representations (data entry chart, table, and graph), and coordinated them with the simulation (often by varying the parameters), they can explore the notion of half-life. It is important to note that for the base one-half, the half-life equals a single time period (or dice roll). Students must come to believe that they can identify an interval that corresponds to the decay of half of the substance, and understand why that interval is constant (and, in the case of probabilities, it is approximate). Finally, it is fundamental to understanding an exponential model, that for any interval of the same number of rolls or time periods, the ratio of the final to the

initial population size is constant. In this way, explorations of half-life should produce a deeper understanding of the underlying syntactical model (using the model distinctions in the sense of Lehrer and Schauble (2000)). A model is syntactical when an examination of its 'grammatical' structure produces its own insights, which can then be mapped onto the circumstance or phenomena. Thus, because a fundamental property of the exponential function is that a horizontal shift (translation) is equivalent to a vertical dilation (stretch), the idea of half-life can be naturally modelled within it.

Finally, such syntactical generalisations become tools in their own right to facilitate transference to new situations. Modelling provides a means to establish how students can develop 'schemes' which permit them to see mathematics in the world around them, as predictive and explanatory. This brings us full circle on the problems that spurred the development of constructivism originally: over-reliance on procedural knowledge and a lack of transfer. Constructivist approaches and the development of a modelling perspective can serve as powerful antidotes to these shortcomings.

While a complete treatment of these topics is not possible in this paper, we hope that this discussion serves to make the ideas of the theory of constructivism clearer and more relevant to the actual practice of science and mathematics education. We have sought to focus on a few of the fundamental properties of the theory while demonstrating how that theory is evolving through work on the ideas of modelling. Those central ideas include genetic epistemology, modelling, consideration of alternative conceptions, the use of hands on materials and technologies, the coordination of representations and the ways in which syntactical properties can emerge from modelling activities.

Conclusion

Overall, constructivism has had an impressive impact on mathematics education, in that it has propelled children into the forefront of activity and asked genuine questions about how to make effective use of the resources, language, inscriptions, and ideas they bring to the enterprise of learning. It has produced many practical accomplishments, from curricula to new technological tools, and documented a number of substantial considerations of student thinking about which all teachers need to know. Because of the theory, we have realised that careful attention must be paid to how students become increasingly aware of what they believe and know, and how this is refined and developed in the company of others. Our views of the role of teachers has been transformed to recognise their critical contributions as stimulators, guides, facilitators and critics – assisting students in developing the fundamental reasoning abilities that are the hallmark of mathematics, as students explore the rich variety of topics in the fields.

In the end, the success of the theory rests on whether it proves generative and useful in driving improvements in practice, as evidenced by greater involvement in a diverse group of students in mathematics and science, by the production of new, inventive and responsibly-designed technologies, and by a more quantitatively and scientifically literate population. Clearly no single theory will accomplish all of these goals, but a number of significant contributions have already been made.

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English as medium of instruction in the new global linguistic order: Global characteristics, local consequences

David Marsh

UNICOM, Continuing Education Centre, University of Jyväskylä, Finland

Abstract

The English language is continuing to establish itself as a global lingua franca in a period of unprecedented globalisation. In the period 1995–2005 educational systems worldwide have shown interest in the adoption of English as a medium of instruction. Teaching through a second language has been successful in certain educational environments. A methodological approach, 'Content and Language Integrated Learning', emerged in Europe in 1995. The period 2000–2006 has seen swift adoption of this educational approach across Europe, at all levels of education. This paper argues that failure to achieve satisfactory educational outcomes when teaching through English are commonplace in certain countries. This failure is compounded by stakeholders seeing barriers to learning in terms of language, as opposed to learning needs, cognition and methodologies. By integrating language and subject teaching, various forms of educational success can be achieved where classrooms comprise learners with diverse levels of linguistic competence.

Introduction

Globalisation, and the impact of the converging technologies, is resulting in the formation of a new global order affecting many societies on an unprecedented scale. Because of the need to have a shared linguistic medium, English has assumed its place as the language of communication within the new linguistic global order.

The choice of English has been viewed from different perspectives. For some, it is part of a steadily developing socio-economic conspiracy. For others, it relates to the need to have a single common utilitarian language. In the past, other languages have assumed the role of 'lingua franca' in a given territory, or socio-economic domain. But now, and over the next fifty years, English is viewed as the language which will be increasingly used to serve the demands of the globalising economies.

Using modelling techniques, researchers such as Graddol (2005) predict that English will become a second language for many, if not most, of the world's citizens by 2050. In terms of number of speakers, English is forecast to be in fourth place by 2050, following the Chinese, Hindi/Urdu and Arabic languages. However, in an increasingly

interconnected and interdependent world, its first position as a lingua franca for socio-economic development over the next one hundred years is in little doubt. It is viewed as an essential lever for success in the globalising economies, and thus it carries the mantle of 'the language of power', just as others such as Latin, have done so in certain regions in the past. For some people, the words globalisation and Englishisation are inseparable.

In the 1990s, we have seen that the educational systems serving countries throughout the world have needed to respond to this rapidly emerging new linguistic reality. English has taken root in science, business, and new key professional domains where it has recently been driven by various forms of e-commerce and outsourcing. Now in 2006, it is being rapidly embedded into the curriculum in a wide variety of countries, from pre-school to higher education.

This is an inevitable step if education is to adapt to the global linguistic ecology which is in a process of unprecedented change now at the beginning of the twenty-first century. English is being widely developed on two levels. Firstly, it is being increasingly introduced earlier, and more extensively, in the form of language teaching. Secondly, it is replacing other languages as a medium of instruction.

English as medium of instruction

The adoption of English as a medium of instruction may result in positive or negative educational outcomes.

Caustically referred to as the language of instruction, if not occasionally destruction, adoption of English as the medium of learning is responsible for widespread school wastage in various continents. In some of the poorest countries in the world, the use of a foreign language such as English as the medium of instruction in schools is directly linked to educational exclusion and failure.

In some continents, attempting to learn through English has led to confusion, despair, and high drop out rates. In others it has been introduced using appropriate educational principles leading to successful and sustainable outcomes.

In the developing world, adoption of European languages such as English, French, and Portuguese, has often been driven by practical and political decision-making. Here national language policies may have been implemented to achieve social cohesion and educational development, or other objectives. However, it is how these policies manifest themselves in the classroom which is the key to achieving success or failure.

There have been marked successes in using a second/foreign language as the medium of instruction, just as there have been examples of long-term failure. There has also been a distinct lack of discussion between educators responsible for diverse contexts where the medium of instruction acts as a barrier, or as some form of challenge, in the classroom.

For example, school wastage in some countries in sub-Saharan Africa can be huge. In South Africa alone it is estimated that some three-quarters of children, or more depending on how you read the statistics, fail school (Heugh, 2000). When we look at the overall educational achievement in any country,[1] it is necessary to consider if the medium of instruction acts as a barrier to learning. This is particularly important when

[1] See, for example, `www.pisa.oecd.org`

fluency in the 'adopted' teaching language may be low amongst learners, and possibly even teachers. Although much work has been done on finding means to improve specific subject teaching, rather little has been done on the foundation of all teaching, namely the medium of instruction. Equally, whereas there may have been much focus on language policies in some countries, there has been very little on language practice.

Problems resulting from medium of instruction are by no means specific to developing countries, or those which are undergoing rapid educational overhaul in response to globalisation. These issues are as relevant to some of the wealthier countries in the world, even if for different reasons.

English has been introduced in Ethiopia as a medium of instruction partly to offset the problem of children arriving in school with different first languages. In England, as throughout Europe, the practice is driven by the wish to enhance language competence, and increasingly cognitive competence, and the lifelong opportunities which this may unlock for the learners. Educators serving in these very different educational contexts actually have much in common when we consider how successful learning in a second/foreign language is achieved. The same can be said of those working with different age groups, and within different academic, vocational, or professional disciplines.

If the use of English as medium of instruction creates a 'language problem' then it is necessary to find solutions which are workable in the classroom. If English as medium of instruction results in enhanced overall learning, then it is equally necessary to identify the conditions leading to success and communicate these across educational sectors.

On a personal note, I have worked with representatives of educational systems in different continents struggling with problems relating to the use of a foreign language as medium of instruction. In searching for solutions, they have tended to be guided towards increasing language learning, sometimes based on a blend of grammatical, lexical and communicative input. This may be admirable, if resources and time are available. But there is a faster track which can be taken which combines knowledge of the language alongside development of skills in using the language across the curriculum. This is a question of methodology. It draws on successes achieved and extensively researched, often under terms such as bilingual education, or some twenty others, whereby language-sensitive methodologies are introduced within an integrated curriculum.

Regardless of what language or educational policy-makers decide, it is the social microcosm of the classroom which reflects the successes or failures of any nation's citizens in the future. Where success is achieved, it is usually bound to the methodologies used by teachers across the curriculum. Teachers from pre-primary to higher education can upgrade their work when language acts as some form of barrier in the learning context, but they need access to the knowledge and skills now increasingly available.

Curricular integration

The demands of the modern world resonate directly through to the curriculum. The speed and pressures resulting from globalisation, and impact of the converging technologies, mean that education is responding to the knowledge and skills demanded in an increasingly 'integrated' world. The Europe Union initiative, Education and Train-

ing 2010, and ongoing global discussions regarding the General Agreement on Trade and Services (GATS) and educational provision, are resulting in pressure being placed on further integrating parts of the curriculum through all educational sectors. 'Integrated learning' is thus increasingly viewed as a modern form of educational delivery designed to even better equip the learner with knowledge and skills suitable for the global age.

Integration of subject matter invites alternative teaching and learning paths. The traditional profile of the teacher as a 'lone rider' doing his or her subject in isolation from others is clearly under threat. In Europe it can be argued that higher performing economies also show advanced forms of curricular integration. If you take a subject such as Environmental Sciences, as taught in primary and secondary sectors, this can be clearly seen. The subject has long been found within specific academic areas such as geography or chemistry. But recently, it has evolved as a significant curricular subject which draws on input from a range of fields from sociology through to physics, chemistry through to mathematics.

Integrating language and content within the curriculum is one example of this type of educational development. This has been done in some way by language educationalists for many years, often with promising results. But the amount of time available for 'language teaching' has often been restricted to such an extent, that the potential benefits have not been readily realised. When we take a situation in which there is 'teaching through the medium of a foreign language', possibly alongside language teaching, then new opportunities surface.

Emergence of content and language integrated learning

The term Content and Language Integrated Learning (CLIL) was adopted by European experts in 1996 as a generic 'umbrella' term to refer to diverse methodologies which lead to dual-focused education where attention is given to both topic and language of instruction. It is used to describe any educational situation in which an additional (second/foreign) language is used for the teaching and learning of subjects other than the language itself.

Although the term is recent, it is used to describe forms of dual-focused learning which have been in existence for many decades in certain parts of Europe, and beyond. It covers some twenty or more educational approaches which share common methodologies. Having previously been found only in special regions, or elite forms of education, it is now relevant because of the widespread introduction of foreign languages such as English, as medium of instruction in mainstream educational contexts.

CLIL can be realised using very different models. Each is determined by the context of the school or university environment, the subjects taught, and the learners involved. It invites a re-conceptualisation of how we consider language use and learning, the learning of subject matter, and often use of the new technologies. It enables development of an integrated educational approach which actively involves the learner in using and developing the language of learning; the language for learning; and language through learning (Coyle, 2000). From a content perspective it has been referred to as education through construction, rather than instruction (Wolff, 2006), and from the language view, using languages to learn and learning to use languages.

CLIL is an approach which is essentially methodological, and is easily misunderstood. Changing the medium of instruction from one language to another in an educational context does not automatically qualify as an example. It requires use of dual-focused language-sensitive methodologies alongside changing the vehicular language. What we are witnessing, worldwide, is rapid adoption of English as medium of learning, from kindergarten in East Asia, through to higher education in Europe. Much of this is being done without adaptation of teaching and learning approaches, and it is likely that there will be negative consequences, as already noted, in relation to some developing contexts.

The CLIL 'generic umbrella' includes many variants. Some of these may be considered as primarily language teaching. Some can be seen as mainly content teaching. The essence of CLIL leads to it having status as an innovative 'new' educational approach which transcends traditional approaches to both subject and language teaching.

When CLIL is incorporated into the curriculum, language takes its position at the centre of the whole educational enterprise. All teachers take responsibility for nurturing its development in the classroom. This is because successful learning depends on the amount, quality, and richness of input. Yet, not all input becomes intake. And if there is limited intake then there will be equally limited opportunities for output which is the realisation of meaningful language usage, and successful content learning. In the successful examples of CLIL all teachers consider themselves to be responsible for language development to a greater or lesser extent, even if the language focus is very, very small indeed.

These teachers find means to adapt the way they teach so as to take account of the extra demands present due to the language medium not being the mother tongue of the learners. But how do they adapt their methods and according to what core structure?

CLIL involves use of language-sensitive methodology which simultaneously develops message, medium and socially-oriented communication. Over the last thirty years the language teaching profession has been heavily influenced by the prevailing philosophy known as the communicative or functional approach. This assumes that we best learn languages when we are in a communicative context, and builds on the idea that the way we learn our first language can be partly used to enable us to learn other languages. This functional approach to language learning underpins some of the methodologies often used through CLIL. However, it must be stressed that CLIL does not prescribe that the major stress is on learning the language, or the content. In one class, at a given time, extra stress may be on language. In another, at another point in time, it may be on the content. The point is that both content and language are interwoven into the curriculum, and the realisation of that curriculum in classroom practice. This integration revolves around the type of subject learnt, the cognitive demands involved, and the pupils' linguistic load.

Constituents of content and language integrated learning

The implementation of CLIL is based on four main principles. These are Cognition, Community, Communication, and Culture. These four principles feed into the methodological approach which integrates focus on the message (topic of learning); medium (language of, for and through understanding the medium) and social (interaction with

others to enhance overall learning).

Wolff (2006) comments on this as follows:

> CLIL theoreticians argue that the learning environment created by CLIL increases the learner's general learning capacities and also his motivation and interest. The integration of content subject and language creates a learning environment which cannot be set up within isolated subject or language teaching. A CLIL classroom which is set up according to modern educational principles is a kind of workshop in which learners are not simply inundated with school knowledge but in which the reality of the school is connected with the reality of the world outside. The fictional world of the language classroom is substituted by something more real which interlinks with the world outside.
>
> CLIL theoreticians also focus on the learner. They argue that in CLIL the separate roles of the learner as a foreign language learner and a content subject learner merge into one role. He or she acquires the concepts and schemata of the content subject first in another language; this process is similar to first language acquisition where the child acquires the linguistic signs and the underlying concepts at the same time. Especially for the higher-ranking scientific facts and processes he or she builds up new concepts which are not influenced by everyday concepts developed in the learner's mother tongue. In CLIL the learner's concepts are foreign language based, the mother tongue concepts build on these foreign language concepts because the learner gets into contact with specific parts of the world around him first via the foreign language.

The four guiding principles means that the learner works with an interface in which cognition (the thinking skills and problem-solving approaches specific to that particular topic); community (the development of the self-awareness of the learner with respect to the content, him/herself as a learner, and the purpose of learning in the wider environment be it at school, university, or the surrounding society); communication (interaction with others and the language domains specific to the topic); and culture (how the learner engages with the language and content, and the discourse features required to both learn and communicate), are all interlinked.

The principle which is now increasingly under the spotlight in CLIL research is cognition. Research on the language and communication advantages of this approach has been ongoing for some time. The huge volume of work carried out on immersion in Canada during the 1970s and 1980s is an early and major part of this resource. It appears that the learner's linguistic development is accelerated during the process, not only in terms of grammar and lexis, but also in terms of handling complex input and concepts. This has sparked interest in looking more closely at the cognitive advantages of the methodology.

For some researchers the importance of Cognitive Academic Language Proficiency (CALP) (Cummins, 1984) remains a key foundation. Others look at this form of language competence in terms of the (Bloom) taxonomy where knowledge, comprehension, application, analysis, synthesis and evaluation are the basic categories by which to apply methods and guide the learning process (Bloom and Krathwohl, 1977).

CLIL involves learning which requires acquiring new concepts and skills. We should not assume that we learn in the same way in the foreign language as in the mother tongue. Firstly, learners often need extra teaching input to understand the concepts and secondly, these may differ across languages and cultures. Thus CLIL methodologies focus heavily on the cognitive demands of a given activity, often using even greater levels of visualisation and co-operative learning (as in peer and group work), scaffolding (as in providing the learner with the means to learn with teacher support available when appropriate), and a constant movement from practical lower order thinking skills through to higher thinking skills.

This is more than language learning, and it differs to mother tongue content learning. It is a blend of both, and implementation requires certain methodological competencies on the part of any teacher.

There is actually little reason why much of the cognitive advantage cannot be achieved in mother tongue medium education. One can only hope that this is so in many parts of the world. However, experimentation with CLIL has revealed that changing the language of instruction can activate significant change of how teachers teach and learners learn, within a given school. Thus, the change of medium of instruction acts as a catalyst for overall educational improvement. But there are two other very important factors at play specific to learning through a second language. One relates to thinking skills and the brain, and the other to motivation.

Some landmark research studies (Mechelli, Crinion and Noppeney, 2004; Bialystok, Craik, Klein and Viswanathan, 2004) point to advantages of cognitive processing in those who can think and problem solve in two languages. Because of the technology increasingly available, more studies are now examining if and how the ability to think and work in more than one language can lead to an overall higher level of mental agility. The use of CLIL methodologies enables the learner to start processing possibly complex concepts at an earlier stage than might have been possible if they had only been exposed to the language in more limited environments such as language lessons. If we consider learners that need to study in a foreign language then application of any educational methods which can accelerate and sustain this become ever more relevant.

CLIL is widely, but less scientifically, reported as leading to increased learner motivation. It is hard to prove that CLIL methodologies do indeed result in classes of more highly motivated learners than those in equivalent mother tongue education. There are many anecdotal reports, and equally many reasons why this may be the case. But in terms of English as the vehicular language there are some important insights which should be considered.

Firstly, good CLIL practice is an educational innovation which appears to suit the new ‘converging technologies’ mindsets found in Generations Y (born between the years 1982 and 2001) and the incoming Generation C (born between the years 2002 and 2025). The mindset orientation of Generation Y is particularly focused on immediacy, as in learn as you use, use as you learn – not learn now, use later. This suits the integrative and instrumental methodologies common to both CLIL and the absorption of a utilitarian command of English through the new technologies. It is not yet possible to know if the emergence of Generation C, as adults, will see further major generational shift with respect to preferred learning styles and strategies.

Secondly, Generations Y and C also share another characteristic, namely the de-

velopment of a bicultural identity. It is increasingly difficult to consider English as a foreign language for large cohorts of the world's educated populations because of its positioning as a second language. The world is witnessing the emerging role of English as a second language for bicultural individuals who have a dual identity. They use their first language for mainly localised communications, and English as the key for accessing the global environment (Arnett, 2002; Wright, 2004). This is a major driver in providing learners with a positive attitude towards the language itself. But it can only be realised if learning through the language is not a barrier to successful learning.

Identifying a theoretical basis for CLIL

CLIL is an educational approach where experimentation and application have largely preceded theoretical description. The wish to accelerate language learning, alongside the need to lower the threshold for learners studying in a foreign language, has led to pioneers in schools experimenting with various educational applications. Some of these draw on second language acquisition, others on foreign language learning and applied psycholinguistics. As time progressed and positive results were reported by teachers, researchers started to examine how CLIL might be different to language teaching and subject teaching, and on what grounds it could enhance overall learning. In terms of language, one widely held assumption is that it provides a naturalistic way of learning not usually attainable in a language class. In relation to content learning, it was assumed that the pressure of accommodating a dual focus in the classroom often led to a re-thinking of how best to teach the content itself and ensuing adaptive learning behaviours. The theory which is now viewed as helping us understand why CLIL appears to offer good results is constructivism (social and cognitive).

Huitt (2003) observes that 'it is the individual's processing of stimuli from the environment and the resulting cognitive structures, that produce adaptive behaviour, rather than the stimuli themselves'. CLIL places emphasis on the learner simultaneously interacting with both language and content so as to foster problem solving and overall conceptualisation. Through methods which are heavily focused on group work and learner autonomy, the learner relies heavily on relating back to knowledge in the first language (thus relating new information in relation to both prior first language understanding, and new comprehension in the second language). If the linguistic and cognitive advantages of CLIL methodology are to be understood in terms of enhanced learning, then it is possible that learning by construction methods enable more students to learn according to preferred learning styles than can be achieved through learning by instruction.

The principles of the constructivist approach, drawn largely from cognitive psychology, are summarised by Bruner (1990) as follows:

- Instruction must be concerned with the experiences and contexts that make the student willing and able to learn (readiness).
- Instruction must be structured so that it can be easily grasped by the student (spiral organisation).
- Instruction should be designed to facilitate extrapolation and or fill in the gaps (going beyond the information given).

Conclusion

There is much discussion about the global spread of English as a medium of education. There have been major achievements over the last twenty years in how to teach English as a second/foreign language. Some approaches to subject teaching have developed radically, others less so. This is also the case with how teachers teach.

There has been a huge impact on our societies resulting from the new technologies, especially in how we access and filter information. There has been equally significant change in what we expect of people in working life, and how we should prepare them even better for the challenges that they will increasingly face.

This has led to a seachange in educational philosophy resulting in how we view and handle education. When the medium of instruction is not the first language of the majority of learners, then the importance of change becomes acute. An increasingly integrated world has led to increasingly integrated curricula and methodologies. CLIL is one example.

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Oral and Poster Session Papers

Mathematics

The effects of preparatory year courses on students' performance in first calculus courses at university: The case of KFUPM

B. Yushau, M. H. Omar and H. Al-Attas

Department of Mathematical Sciences, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

Abstract

This paper presents the results of a longitudinal study conducted to investigate the effect of preparatory-year programme courses on students' performance in first calculus course. Another variable included in the study is the role of the semester in which students take the first calculus courses. The data consists of grade records of more than two thousands students tracked over seven semesters, and comes from bilingual Arab students studying at an English medium university. Analysis of this data reveals that all the variables contribute with varying degrees in explaining students' performance in first calculus courses. The implications of this finding for academic policy are discussed.

Background of the study

English language is gradually becoming the main language of instruction in higher education institutions within the Middle East. The trend is much more in area of sciences, medical, and engineering courses. However, the Arabic language remains the main language of instruction at the primary and secondary levels. At the university entry level, different Middle Eastern universities use different programmes to bridge the gap that this language switch may cause. The most common approach is a one-year preparatory programme. In addition to bridging the language barrier, the programme also aims at creating a conducive atmosphere for a smooth transition from secondary school to university.

King Fahd University of Petroleum and Minerals (KFUPM) is one of a few universities in Saudi Arabia in which the language of instruction is officially English. Consequently, all students admitted to KFUPM are required to complete a one-year preparatory programme before starting their undergraduate studies. This programme mainly consists of two courses of intensive English language instruction (ENGL 001

and ENGL 002), and a review of some basic secondary school mathematics comprising MATH 001 and MATH 002. In addition, students take courses related to graphics, a mechanical engineering workshop, and physical education during the preparatory year.

According to the Undergraduate Bulletin of KFUPM (2001), the main aim of the preparatory-year programme is to prepare students for undergraduate study, especially with regard to the new language of instruction.

The preparatory year programme at KFUPM is a two-semester programme. However, students are given a maximum of three semesters to complete the programme. The final grades earnt by the students in this programme are not considered in the calculation of the students' cumulative grade point average (CGPA) for the undergraduate programme. Nevertheless, the grades are recorded in the students' transcript together with the semester grade point average (GPA) and CGPA. More notably, a student's performance on the preparatory year programme is largely considered as a predictor of his success in the undergraduate programme (Al-Doghan, 1985).

It should be noted that though KFUPM is a science and engineering oriented university, it is not automatic for all admitted students to secure a place in engineering and computer science courses after 'successfully' completing the preparatory-year programme. For a student to go for any academic programme of his choice, he has to meet some minimum entry requirement based on the preparatory-year mathematics and English courses.

After passing the preparatory-year courses, students follow two different mathematics strands. Those students posted to the college of sciences, engineering, and computer sciences are required to take a more rigorous mathematics strand which begins with Calculus I, while others go for a different set of mathematics courses.

Our focus in this study is on students taking the Calculus I strand. The reason for choosing Calculus I is because it is largely considered as the backbone of the calculus series. On the other hand, the typical calculus sequence of courses is considered the nucleus of modern mathematics and vital for any science and engineering related courses, in which KFUPM specialises.

As in many other college algebra and pre-calculus courses, the aim of preparatory mathematics (MATH 001 and 002) at KFUPM is to prepare students for these calculus courses. However, not much is known about the level of students' preparedness for the calculus series after completing the preparatory-year programme. Therefore, the aim of this paper is to examine the effect of the four major preparatory-year courses (ENGL 001 and 002, MATH 001 and 002) on students' performance in the first calculus course at KFUPM. In addition, we intend to investigate the effect of the semester in which students take Calculus I.

Method

The participants whose grades formed the data of this study were male students with an average age of 19 years, mostly in the first year of university life after the completion of their preparatory-year programme. Almost all these students have Arabic as their first language as well as it being the language of instruction during their previous schooling. Most of them have had little English background at the time of admission.

Data

The data for this study was collected longitudinally from the Autumn 2002 semester to Autumn 2004 and comprised seven semesters in total. The number of students that took Calculus I in all the seven terms are presented in Table 1.

Year	Term	Frequency
Autumn 2002	21	561
Spring 2003	22	161
Summer 2003	23	104
Autumn 2003	31	450
Spring 2004	32	201
Summer 2004	33	114
Autumn 2004	41	491
	Total	2082

Table 1: Number of students from each Term.

Letter grades for all English and mathematics courses in the preparatory-year programme were recorded for each student, as well as that of Calculus I. All students who went through the orientation programme at KFUPM and progressed through Calculus I provided the data for this study.

Procedure

To investigate the relationship between orientation programme variables with students' performance in Calculus I at KFUPM, a multiple regression procedure was utilised in this study. The dependent variable for the analyses is the students' numerical grade in Calculus I. The number of students with these letter grades and corresponding numerical grades in the regression analyses are given in Table 2.

Grade		Frequency
Letter	Numerical	
DN or F	0.00	69
D	1.00	201
D+	1.50	221
C	2.00	385
C+	2.50	357
B	3.00	328
B+	3.50	227
A	3.75	197
A+	4.00	97
Total		2082

Table 2: Calculus I response profile.

The independent variables on the other hand, are the students' numerical grades in ENGL 001, ENGL 002, MATH 001, and MATH 002 (ordered as DN or F, D, D+, C,

C+, B, B+, A, and A+). Other independent variables include the academic Term (021, 022, 023, 031, 032, 033, and 041) in which the students took Calculus I.

Results and discussion

In the course of this investigation several models were developed using regression analysis. However, only the pertinent models are reported here. Table 3 gives three of these models and variables therein. The results of the three models are summarised in Table 4 in descending order. The table also reports the models, the multiple correlation R-values, R^2-values, Adjusted R^2-values with associated degrees of freedom, F-values and p-values.

Model 1	Model 2	Model 3
T21	T21*	T21
T22	T23*	T23*
T23	E2*	E2*
T31	M1*	M1
T32	M2*	M2*
T33		M1M2*
E1		M2T21*
E2*		M2E1T32*
M1*		E1E2T32*
M2*		

M1 = MATH 001, M2 = MATH 002, E1 = ENGL 001,
E2 = ENGL 002, T21 = Term 21 and likewise,
M1M2 = interaction of M1 and M2,
M2T21 = interaction of M2 and T21,
M2E1T32 = Interaction of M2 and E1 and Term 32,
E1E2T32 = Interaction of E1 and E2 in Term 32.
*= significance at alpha 0.05.

Table 3: Summary of the variables in the best three models.

As can be noticed from Table 4, all three models are statistically significant at alpha 0.05, and very close to each other in terms of their accuracy. However, Model 3 is the best model and explains about 36 per cent of the total variance in the Calculus I grade.

Model	R	R^2	R^2 (adj)	df (Model)	df (Error)	F statistic	p
1	0.5959	0.3551	0.3516	11	2070	103.6	<0.0001
2	0.5945	0.3534	0.3518	5	2076	226.88	<0.0001
3	0.5998	0.3598	0.3570	9	2072	129.39	<0.0001

Table 4: Multiple regression model summary.

Table 5 shows the summary of the best model and the variables that contributed significantly in the model. The first column of Table 5 is the name of the variable, followed by degree of freedom, the estimate of the parameter, standard error, and the associated t-value, and p-value. The best model seems to suggest that the academic subjects of the preparatory year are important predictors of Calculus I performance. Of the academic variables, ENGL 002 and MATH 002 provide a significant contribution to the best prediction model. Among the academic terms, semester 023 appears to be the only significant term when compared to the reference term 041. This simply means that from the perspective of the model, students taking Calculus I in different semesters, were not very different in ability except for those taking the course in term 023.

Variable	DF	Parameter Estimate	Standard Error	t-value	$\Pr > \|t\|$
Intercept	1	0.5155	0.2603	1.98	0.0478
T23	1	0.2576	0.0814	3.16	0.0016
E2	1	0.0658	0.0319	2.07	0.0390
M2	1	0.3062	0.0904	3.39	0.0007
M1M2	1	0.0840	0.0305	2.76	0.0059
M2T21	1	-0.1311	0.0523	-2.51	0.0122
M2E1T32	1	-0.0609	0.0301	-2.02	0.0432
E1E2T32	1	0.0763	0.0299	2.56	0.0106

Note: Only the significant variables are reported here.
The non-significant variables were reported in Table 3.

Table 5: Summary of the value of each coefficient with standard error, t-statistics, and p-value.

There are also several significant interaction effects in the best model. First important interaction is M1M2 (interaction of MATH 001 and 002). Although MATH 001, which was crucial in Model 1 and 2, is surprisingly not significant in the best model, its joint effects with MATH 002 appear significant as a predictor of Calculus I performance in the best model. In addition to the M2 effect, the interaction effect of the variables M1 and M2 implies that, beyond that already explained by M2, the common core concepts and skills found in the preparatory-year mathematics curriculum as represented in both mathematics courses are crucial as a predictor of Calculus I performance. This also indicates that some knowledge and skills in MATH 001 reinforce the knowledge and skills in MATH 002 to provide a better prediction of Calculus I performance. Another significant interaction effect is M2T21 (that is, the joint effects of MATH 002 and Term 021). This interaction appears to subtract from the gradient of the regression line representing MATH 002 at Term 021. That is, for Term 021, the profile of Calculus I student performance is better explained by a gradient that is smaller than what is represented by MATH 002 effects alone. The third interaction effect M2E1T32, is the three-way interaction effects of MATH 002, ENGL 001 and Term 032. Although neither ENGL 001 nor term 032 were significant by themselves, their joint effects with MATH 002 show that the prediction should be discounted by 0.0609 numerical grade units. This implies that the student's ENGL 001 skills and MATH 002

knowledge, when applied to the context of the semester in which they took Calculus I, Term 032, requires a smaller predicted numerical grade than in other Terms. Lastly, the interaction effects E1E2T32 is also significant. This effect represents the common knowledge and skills that are in the preparatory-year English curriculum as represented in both English courses that students carry into the context of semester term 032. This joint English knowledge and skills in term 032 requires a higher predicted Calculus I score than in other terms beyond those already warranted by the ENGL 002 effect.

Variable when added last	R^2 improvement
E1	<0.010
E2	0.030
Both E1 and E2	<0.030
M1	0.070
M2	0.100
Both M1 and M2	0.270

Note: The added last analysis was conducted with only the academic variables in the model.

Table 6: Summary of the contribution of preparatory-year courses in predicting Calculus I performance.

For completion of the analyses, a regression model with only the academic variables in the model was fitted with each of the variables in Table 6 added in last to see the effect of the course in question when other academic variables are already used as predictors of Calculus I performance. The four academic subjects in the preparatory year (ENGL 001, ENGL 002, MATH 001, and MATH 002) together explain slightly above 33 per cent of the total variance. Contrast this with total variance explained by the best models (36 per cent). This has shown that adding other variables (including academic Term) in the model add only around three per cent to the model. In these analyses along with the remaining academic variables, MATH 001 explains only seven per cent, MATH 002 ten per cent, ENGL 001 less than one per cent, and ENGL 002 three per cent. On the other hand, jointly, the two mathematics courses explain twenty-seven per cent of the total variance, while the two English courses explain barely more than three per cent.

As noted earlier, surprisingly ENGL 001 and MATH 001 did not contribute significantly to the best model as stand-alone effects, but their joint effects with other variables can be readily seen as crucial predictors of success in the Calculus I course. This means, the intact curriculum of MATH 002 is needed more as a pre-requisite of Calculus I than that of MATH 001. Furthermore, MATH 001 as a pre-requisite for MATH 002 can be seen as providing more of a supportive role to MATH 002 as the main pre-requisite of Calculus I. This should give some empirical support to the new policy in the preparatory year that for a student to go to either an engineering or a computer-related course, he should get at least a passing grade of D in MATH 001 and C in MATH 002 as a placement requirement.

Limitation of the study

The results of this study should be interpreted with caution due to a number of factors. Firstly, our data collection method and analysis are quantitative in nature. So, no attempt was made to qualitatively (through interviews or classroom observations) investigate the same problem. Had this approach been used, a different result may have been obtained. Therefore, future research may possibly look into this factor to corroborate the result. Secondly, participants were Arab male students only, with little background in English. It would be interesting to determine whether the findings would be replicated in a women's university in Saudi Arabia. Thirdly, the variables examined here are certainly not exhaustive and other factors such as student reading habits, level of motivation, etc. could also be included in a future study.

Conclusion

As the preparatory-year programme is becoming the main bridge between secondary school and the university due to students' language constraints, not much is known about the effect of such a programme on students' performance in higher mathematics courses, which are largely considered as the backbone of science and engineering oriented courses.

In this paper we have investigated using multiple regression analysis on the effect of the preparatory-year academic courses, and the term in which students took Calculus I, on the students' performance in the first calculus course at KFUPM. The three models reported earlier seem to suggest that the academic subjects of the preparatory year are important predictors of Calculus I performance with the best model explaining about 36 per cent of the students' numerical grade in Calculus I. However, MATH 002 and ENGL 002 seemed to contribute more than other main effects variables. Other factors that contributed significantly in the best model included some interaction of the preparatory-year courses. However, it is interesting to note that ENGL 001 and MATH 001 alone did not contribute significantly to the final model. They have an effect only when they interact with other variables. On the other hand, the variable term is also not significant with the exception of term 023. A plausible explanation for this might be the superior mathematics abilities of the student cohort in this summer semester compared to the other semesters.

The findings in this study tend to indicate that as far as science and engineering oriented courses are concerned, the students' mathematics background is very critical, and therefore should be given attention. This result corroborates with many studies in the literature (Begle, 1979; Tuli, 1980; Jamison, 1994; Kelly, 1999; Soares, 2001; Yushau, 2005). Furthermore, the variation found in the role of MATH 001 and MATH 002 in predicting Calculus I grades seems to suggest that if the aim of the preparatory-year mathematics programme is to prepare students for the calculus series, then there is a need to streamline the syllabus, and emphasis should be given more to MATH 002, as it plays a greater role in predicting students' performance in Calculus I.

Similarly, students' proficiency in English – the language of instruction plays some positive role in predicting students' performance in Calculus I. Many studies have corroborated this finding (Taole, 1981; Ferro, 1983; Al-Doghan, 1985; Cuervo, 1991; Maro, 1994; Han, 1998; Lim, 1998; Yushau, 2005). Therefore, language issues should

be taken into consideration whenever students are learning mathematics in a second language.

It is our hope that, due to lack of research in this area, the data presented in this study will serve as a starting point, and hopefully contribute to the field of mathematics education. Furthermore, the findings in this study may help university administrations in policy making regarding student placement into academic programmes after completing the preparatory year, and in streamlining and prioritising the syllabus. It can also be useful for other universities with similar preparatory-year programmes.

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Using the computer algebra system DERIVE to investigate solutions of differential equations

L. L. Raj

Mathematics Department, Higher Colleges of Technology, Abu Dhabi Men's College, Abu Dhabi, United Arab Emirates

Abstract

Students find solutions by using routine techniques for specific types of differential equations. Often little more is done once the solution has been written down. More meaning and interpretation can be given to solutions of differential equations if students are able to visualise them. This paper describes the author's use of the computer algebra system, DERIVE, to help engineering mathematics students at the Higher Colleges of Technology, Abu Dhabi Men's College to investigate their solutions to first-order differential equations. Through visualisation, students can give meaningful interpretation to symbolic forms and reduce anxiety with the mathematical language. With this comes better understanding, a development of interest, motivation to find out more, and even some enjoyment in the subject.

Introduction

Students at the Higher Colleges of Technology are currently able to enter into Diploma, Higher Diploma, and Bachelor Degree programmes. The Diploma programmes introduce students to general and specific occupational skills, develop basic proficiency in English, computing and mathematics, and lead to occupation-specific skills at the technician level. The Higher Diploma programmes are three years in length and involve a combination of theoretical knowledge and practical applications at the technologist level. There has been a major move over the past years to shift from a teacher-centred to a more learning-centred approach. Students at all levels are encouraged to assume greater responsibility for self-directed learning. All students now have laptops. Classrooms are equipped with smart-boards allowing technology to be readily integrated into the classroom.

In mathematics, our engineering students are introduced to first- and second-order ordinary differential equations in the second year of their Higher Diploma programme. Students find solutions by using routine techniques for specific types of differential equations. Often little more is done once the solution has been written down. There is little appreciation for what the result represents. More meaning and interpretation can

be given to solutions of differential equations if students are able to visualise them. Through visual stimulation, students can give meaningful interpretations to symbolic forms and reduce their anxiety with the mathematical language. With this comes better understanding, a development of interest, motivation to find out more, and even some enjoyment.

Our teaching should not be a pure transfer of notions and techniques. Students need to be stimulated to have a more critical attitude towards the solution of the problem described by a differential equation. We should not only concentrate on 'how to solve a differential equation', but also try to bring some meaning to the result. Students should ask themselves questions, not passively accept their results. The computer algebra system, DERIVE, is simple and straightforward to use and fosters more critical, significant, and effective learning. It can be of assistance to our engineering mathematics students in investigating first-order differential equations, bringing deeper insight to their solutions.

Direction fields

A first-order differential equation describes the relationship between a function and its first derivative or slope. Students can begin to investigate the solutions of such differential equations by looking at their direction fields (or slope fields). In examining how solutions behave, students are concerned with the qualitative behaviour of the differential equation as opposed to its quantitative behaviour. They can observe characteristics such as increase, decrease, maxima, minima, oscillation, and bounding. DERIVE allows students to construct direction fields easily and quickly using a simple command. First, students have to express the equation in the form $\dfrac{dy}{dx} = f(x, y)$ and then use the `DIRECTION_FIELD` command.

Its structure is `DIRECTION_FIELD`$(f, x, x_0, x_m, m, y, y_0, y_n, n)$ which approximates to a matrix of two-component vectors that when plotted displays a direction field for the equation. The value of x varies from x_0 through x_m in m steps, and y varies from y_0 through y_n in n steps. Consider the first-order differential equation

$$L\frac{di}{dt} + Ri = \varepsilon,$$

which models the current i at time t in a simple electric circuit with a resistance of R ohms, an inductance of L henries, and an electric potential difference of ε connected in series. For $R = 16\ \Omega$, $L = 4.0$ H and $\varepsilon = 60$ V, the equation becomes

$$4\frac{di}{dt} + 16i = 60, \qquad \text{or} \qquad \frac{di}{dt} = 15 - 4i.$$

The command `DIRECTION_FIELD`$(15-4i, t, 0, 3, 12, i, 0, 8, 15)$ produces the direction field shown in Figure 1.

From the direction field, students can visualise many solutions and see that the solutions all seem to approach a value of i somewhere between 3.5 and 4 ampères as t increases. They can identify this value by solving the linear differential equation and looking at large values of t. The general solution is

$$i = \frac{E}{R} + \mathrm{c}e^{-Rt/L} = \frac{15}{4} + \mathrm{c}e^{-4t},$$

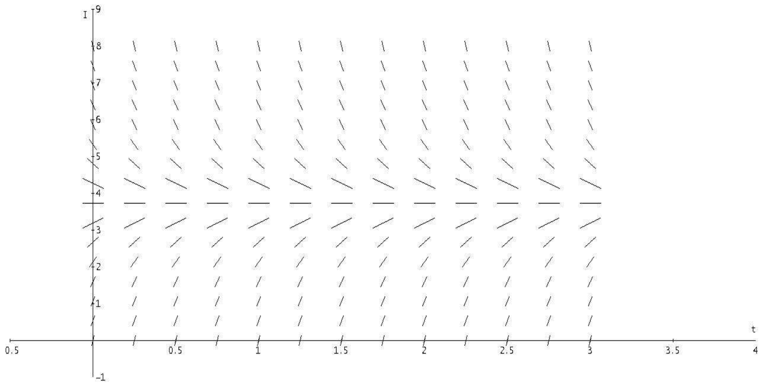

Figure 1: Direction field.

and as $t \to \infty$, $i \to 15/4 = 3.75$ ampères.

Family of solutions

The direction field indicates that there are many functions that share the same derivative. The concepts of general solutions and arbitrary constants are reinforced by visualising the parameterised family of solutions. DERIVE enables the student to superimpose a number of solution curves on the direction field. This can be done using its `VECTOR` function. The command `VECTOR`$(f(x, y, c), c, m, n)$, where $f(x, y, c)$ is the general solution generates a vector of $n - m + 1$ elements each of which is a solution of the differential equation for values of the parameter c from n to m in unit steps. For the electric circuit example, the command `VECTOR`$(E/R + c\mathrm{e}^{-Rt/L}, c, -5, 5)$ allows us to plot eleven curves where c goes from -5 to $+5$. The solution curves are shown in Figure 2.

Particular solutions

Each one of the curves superimposed on the direction field represents a particular solution and the particular solution required depends on some known initial condition. Students can apply the initial condition to find the particular solution and plot its curve.

For our circuit example, using the condition $i(0) = 0$, the particular solution is $i = 15/4(1 - \mathrm{e}^{-4t})$. Its graph is shown on the direction field in Figure 3.

Solutions with DERIVE

Our students in the Higher Diploma programme look at techniques for solving separable and linear first-order differential equations. DERIVE has functions for both these types for general and particular solutions. Once students have become proficient in solving such equations manually, we provide them with DERIVE worksheets to investigate separable and linear first-order differential equations. They solve the equations

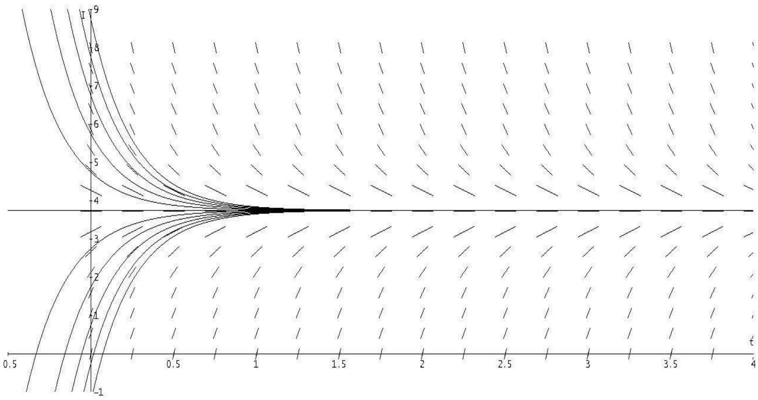

Figure 2: General solution curves.

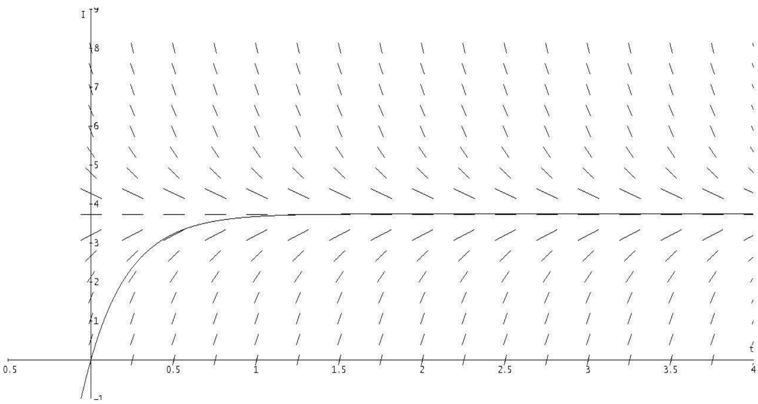

Figure 3: Particular solution.

in DERIVE and concentrate their attention on graphs of the solutions. A typical student exercise is given in the appendix.

Conclusion

The examples above may help to illustrate the applicability of DERIVE, as well as other computer algebra systems, in providing students with visual stimulation and deeper insight into the mathematics involved. The importance of visualisation can hardly be overestimated in general cognitive skill acquisition and problem-solving processes. Pictures activate mental processes such as the perception of spatial relationships, intuitive comprehension of complex processes, or the observation of patterns and, therefore, aid the process of understanding (Schwardmann, 2000). A visualisation advantage in turn can lead to greater motivation and the development of a more investigative atti-

tude (Raj, 1995a; 1995b). The visual emphasis enforces the notion that functions have graphical representations and are not meaningless symbolic sentences. Students need to be encouraged to picture functions. This dual representation contributes to a greater awareness of the mathematics they are performing and enables them to acquire an intuitive feel for the subject (Lindsay, 1995).

The primary focus in education should be on conceptual understanding. Computer algebra systems such as DERIVE can be applied to assist students with reinforcement of concepts. They enable us to communicate mathematics visually and symbolically. When the visual and symbolic attributes of a concept are integrated and emphasised, mathematical understanding will be enhanced giving more insight to the student.

Appendix

An example of a typical DERIVE exercise students would perform in class.

Question 1

(a) Express $x\dfrac{dy}{dx} - 2y = x^4$ in the form $\dfrac{dy}{dx} + P(x)y = Q(x)$.

____

$P(x) =$ ____________________________________

$Q(x) =$ ____________________________________

(b) Use DERIVE to:

(i) Find the general solution of the differential equation.
General solution: ____________________________

(ii) Find the particular solution for the given condition $y = 5$ when $x = 2$.
Particular solution: ___________________________

(c) Plot the graphs of the solutions for values of the arbitrary constant c from -5 to 5 as well as the graph of the particular solution.

Obtain a print out of the graphs and indicate the particular solution on it.

For the above exercise the student would obtain

$$P(x) = -\frac{2}{x} \qquad \text{and} \qquad Q(x) = x^3.$$

The general solution would be found using the DERIVE command:

$$\texttt{LINEAR1\_GEN}(-2/x, x^3, x, y, c)$$

giving $y = x^4/2 + cx^2$. The particular solution would be found using the DERIVE command:

$$\texttt{LINEAR1}(-2/x, x^3, x, y, 2, 5)$$

giving $y = x^4/2 - 3x^2/4$. Graphs indicating a set of general solutions and the particular solution are shown in Figure 4.

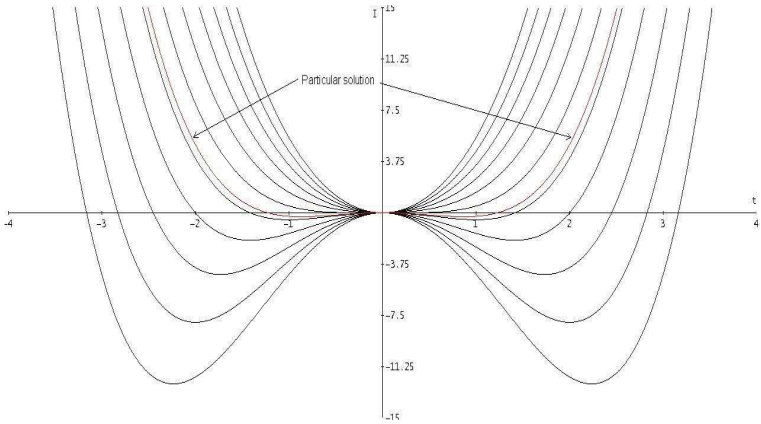

Figure 4: A set of general solutions and the particular solution.

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Numerical integration using MS Excel

M. El-Gebeily and B. Yushau

Department of Mathematical Sciences, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

Abstract

In this paper, we show how the widely available MS Excel spreadsheet program can be used to perform numerical integration. Specifically, we implement the trapezoidal rule and Simpson's rule. Our implementation does not require any programming and the setup needs to be done only once for various problems.

Introduction

The discovery of the differential and integral calculus was a great turning point in the world of mathematics. These concepts have many applications in the sciences, engineering, business, and many other social sciences. However, in many applications, analytical integration and/or differentiation is either not possible (e.g., functions defined by subroutines), or very difficult, depending on the nature of the function. Therefore, numerical approximation is a way out for such problems.

Many numerical methods are currently available for approximating the integral of a function. Two of the most popular ones are the trapezoidal rule and Simpson's rule. These are the first numerical methods students encounter in secondary school.

In this paper, we intend to illustrate how teachers and students can use Excel to implement these numerical methods: Simpson's rule and trapezoidal rules. The nature of the Excel program makes the method easy to implement. With the 'what if' capability of Excel, one can explore different functions by simply changing the function rule. It should be noted that the Excel implementation of these two integration techniques exists in the literature (Oregon State University, 1999; Haggert, 1999). However, our approach is much simpler, more direct, and does not require the execution of any macros. In addition, our worksheet needs no modifications once developed, except for entering the interval of integration and the number of divisions (which is less than or equal to 100 for our particular implementation). This gives us motivation to share our experience with the larger mathematics education community.

Numerical integration with Excel

In this section we illustrate how Excel worksheets can be used to implement the trapezoidal rule and Simpson's rule for numerical integration. The problem is to find a numerical approximation for the integral

$$I = \int_a^b f(x)\,dx.$$

The trapezoidal rule

The trapezoidal rule works by approximating the function $f(x)$ by a piecewise linear function and evaluates the integral of each piece. If the interval $[a, b]$ is divided up into n equal subintervals, each of width $h = (b - a)/h$, then the approximate integral is

$$I \approx \frac{h}{2}\sum_{i=1}^{n}(f(x_{i-1}) + f(x_i)),$$

where $x_i = a + ih$ and $i = 0, 1, 2, \ldots, n$.

We illustrate our approach with the following example

$$\int_0^1 (14x^6 + 7)\,dx.$$

The method is explained as follows. The end-points (initial and terminal) of the interval, and the number of divisions are entered in the cells A2, B2, C2, respectively. The value of h is calculated in the cell D2 by entering the formula `=(B2-A2)/C2`.

To generate the x_is, we take the following steps:

1. In cell E2, enter the formula `=A2`. This copies the value of $a = x_0$ into E2. Figure 1 shows the upper part of the Excel worksheet implementation of the method.

2. The next values are generated with the formula

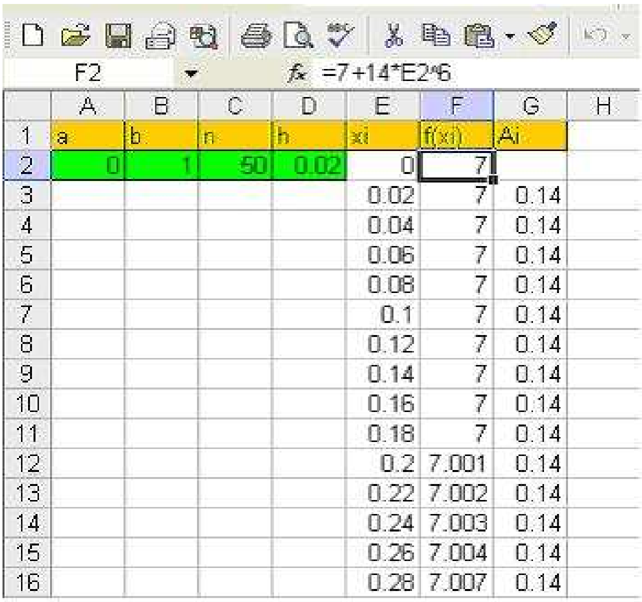
   `=IF(E2>=$B$2,$B$2,E2+$D$2)`

   in E3. This formula adds h to the previous value until we reach the value of b. Afterwards it keeps entering the value of b. This mechanism is used to enable changes in the value of n to get more control on the accuracy of the solution as explained in Step 5.

3. Copy this formula to the next 100 cells or so below E4. Figure 1 also shows a part of the sheet further down, where you can see the value of b being repeated.

4. The function f is entered in the column labelled $f(x_i)$ by entering the formula `=7+14*E2^6` in the cell F2 and copying it along the corresponding cells for the x_i's.

5. We then form the elements of the summation in the trapezoidal rule by entering the formula `=(E3-E2)/2*(F2+F3)` in cell G3 and copy it along the corresponding cells for the x_is. Observe that, instead of using the value of h generated in cell D2, we used the equivalent difference E3-E2. This has two advantages:



F2 f_x =7+14*E2^6

	A	B	C	D	E	F	G	H
1	a	b	n	h	xi	f(xi)	Ai	
2	0	1	50	0.02	0	7		
3					0.02	7	0.14	
4					0.04	7	0.14	
5					0.06	7	0.14	
6					0.08	7	0.14	
7					0.1	7	0.14	
8					0.12	7	0.14	
9					0.14	7	0.14	
10					0.16	7	0.14	
11					0.18	7	0.14	
12					0.2	7.001	0.14	
13					0.22	7.002	0.14	
14					0.24	7.003	0.14	
15					0.26	7.004	0.14	
16					0.28	7.007	0.14	

Figure 1:

(a) The formula produces zeros when we go past the right end-point b. In this way, the final sum of these numbers is not affected by the repetition of $[a, b]$.

(b) It allows the use of the trapezoidal rule with non-uniform divisions of the interval $[a, b]$.

6. The last step is to add the terms in column G to get the approximation of the integral. Select the range of cells that contains the summation terms and then click the sum button ($\sum$) on the tool-bar. The result is shown in Figure 2.

	A	B	C	D	E	F	G	H	I
96					1	21	0		
97					1	21	0		
98					1	21	0		
99					1	21	0		
100					1	21	0		
101					1	21	0		
102					1	21	0		
103							9.003		

Figure 2:

Note:

(a) If you now change the number of divisions n to 100, the new, more accurate approximation will appear in the same cell (G103).

(b) To change the interval of integration all you need to do is to change the values a, b in cells A2, B2.

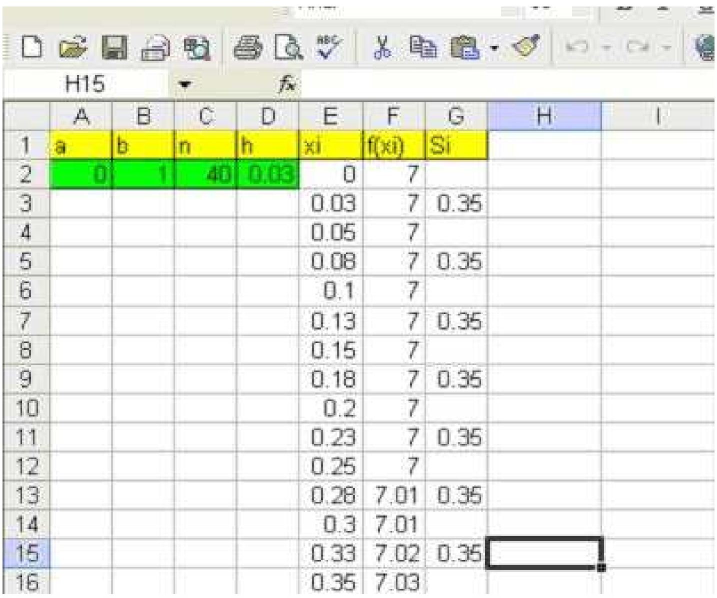
(c) To change the integrated function enter the new formula in cell F2 and copy it to cell F103.

Simpson's rule

Simpson's rule finds an approximation of the value of the integral I by replacing the integrand with a piecewise polynomial of degree 2 and then evaluating the integral over each piece. Simpson's rule is given by

$$I \approx \frac{h}{3} \sum_{i=1}^{n-1} \left(f(x_{i-1}) + 4f(x_i) + f(x_{i+1}) \right).$$

Here the interval $[a, b]$ is divided into n subintervals, each of length $h = (b - a)/n$. The Excel implementation of Simpson's rule is very similar to that of the trapezoidal rule, except for some minor details. Figure 3 shows the upper part of the worksheet implementation.



	A	B	C	D	E	F	G	H	I
1	a	b	n	h	xi	f(xi)	Si		
2	0	1	40	0.03	0	7			
3					0.03	7	0.35		
4					0.05	7			
5					0.08	7	0.35		
6					0.1	7			
7					0.13	7	0.35		
8					0.15	7			
9					0.18	7	0.35		
10					0.2	7			
11					0.23	7	0.35		
12					0.25	7			
13					0.28	7.01	0.35		
14					0.3	7.01			
15					0.33	7.02	0.35		
16					0.35	7.03			

Figure 3:

As you can see from the figure, the table is exactly the same as that for the trapezoidal rule except for the last column. The last column is generated as follows. In cell G3 enter the formula

```
=(E4-E2)/6*(F2+4*F3+F4).
```

Since Simpson's rule spans two subintervals for each entry in the summation, the copying of the formula is done as follows. Select the range of two cells G2, G3 (note that G2 is actually empty). Using the formula copying technique, drag the two cells down to cell G103. The result is that the formula is copied to every other cell. One more thing to notice here is that, in the above formula, the value of h is replaced by the difference over 3 cells divided by 2. In this way, the same skipping is achieved and no problem arises as a result of repeating the values of b. When you select the range G2:G103 and click the sum button, you will see the result 9.000003644, which is more accurate than the result obtained from using of the trapezoidal rule, as the theory predicts. From here it is not hard to see how Excel can be used to implement numerical integration with higher order quadrature rules.

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Improving teaching and learning in science and mathematics

Graeme Ward

Foundation Mathematics, The Petroleum Institute, Abu Dhabi, United Arab Emirates

Abstract

In the year 2006, most mathematics teachers are aware of constructivism and of many of its practical implications. However, the majority have been 'schooled' as objectivists and 'tooled' by behaviouralist training and principles. In addition, management in many institutions operates in the traditional behaviouralist, objectivist mode. Pragmatic decision making driven by budgetary constraints and managerial accountability means that innovation, while openly applauded, is not necessarily fully researched or encouraged when it appears to trespass upon or question the traditional values or methods currently in practice. This paper is an attempt to demonstrate the effectiveness of using constructivism as a referent when implementing new methodologies aimed at improving the quality of teaching and learning as defined by learning mathematics for greater understanding.

Introduction

Most teachers are aware of the term 'constructivism' and have some idea of its effect upon, and its requirements for, 'better' teaching practice. Knowledge is not passively received but built up by the cognising subject. Known as the first principle of (trivial) constructivism (von Glasersfeld, 1989), this conclusion is based upon the findings of biologist Jean Piaget from his research into cognitive theory and the cognitive adaptation (assimilation and accommodation) of organisms. Von Glasersfeld applied Piaget's findings to 'learning theory' and the development of individual knowledge and understanding.

The implications of this first principle of constructivism for teachers are quite clear. If all knowledge is constructed from prior knowledge and experience, then we cannot 'impart' knowledge. We can only facilitate its construction by the individual, and to facilitate effectively, we must be aware of each individual's prior constructions, namely, the interdependent entities of knowledge, understanding, beliefs, values, and heuristic strategies (Schoenfeld, 1992).

Von Glasersfeld's second principle, namely the function of cognition, is adaptive, serves the organisation of the experiential world, not the discovery of ontological reality (von Glasersfeld, 1989), and has even greater implications. Known as the principle of radical constructivism, this statement, supported strongly by empirical, qualitative,

and anecdotal evidence, persuasively combined the arguments[1] of the sceptical tradition[2], the evolutionary theories of Darwin and Wallis[3] and the widespread observations of educational psychologists and classroom practitioners (von Glasersfeld, 1990; Kelly, 1955). The implications of this principle have had an enormous influence on the fields of philosophy, psychology, and educational research. Indeed, all sociological research fields have been greatly influenced to such an extent that qualitative research methodologies with their postmodern, subjective viewpoints have competed strongly with, and even combined pluralistically and/or dialectically with the traditional, objectivist approaches to research and evaluation (Guba and Lincoln, 1989; Denzin and Lincoln, 1997; Bryman, 2001; Settelmaier and Taylor, 2001).

The consequences for the classroom teacher have also been far reaching, and in many cases 'liberating'. While many of us found it difficult to accept that our own personal educational metaphors such as 'an explorer on a voyage of discovery' were no more applicable than that of 'a worm making sense of the "mud" in which it lives', we were freed as practitioners by the realisation that all acts of learning were constructive. At our disposal was an eclectic array of pedagogical methods, each of differing effect and viability dependent upon the past experiences of a varied and ever changing array of students. This is not to say constructivism promotes a pedagogical 'laissez faire'. There are certainly desirable and optimal protocols and procedures (Ernest, 1995; Schoenfeld, 1992; Confrey, 1990), but each must be applied in context. Consequently, each approach in itself is a learning experience for all teachers and students alike and each step in the process an evolutionary one.

Indeed such is the strength of the constructivist paradigm that it has undergone its own evolutionary process, taking 'on board' the many criticisms of its opponents and protagonists alike, and integrating these other viewpoints into its own 'scheme of things'. Typically, the next 'evolutionary' step has been the development of social constructivism. As Confrey (1990) points out, 'the constructive process is subject to social influences. We do not think in isolation'. This has been in response to the widely observed fact that while the act of knowledge forming (construction) may have been an individual 'decision' or accommodation, it was being performed – negotiated, mediated and its viability validated – within a (social) matrix of peers, culture, ethnicity, gender, and numerous other factors enmeshing learners within their own interlocking 'webs of significance'.

In addition to numerous teachers and researchers demonstrating the significance and importance of the social aspects of constructivism (Solomon, 1992; Tobin and Tippins, 1993; Driver, 1995) there has also been research into many of the individual aspects of social constructivism. Areas of interest include the debate of enculturation (of curriculum) versus acculturation (Aikenhead, 1990; Taylor and Cobern; 1998) regarding the issue of an individuals' own cultural identity and life-world understandings being replaced by the valueless, objective, and often alien culture of 'Western science', and the need for a pluralistic, dialectic suspension ('multi-science') of equally valued

[1] Man having within himself an imagined world of lines and numbers, operates in it with abstractions just as God, in the universe did with reality (Giambattista Vico, 1711)

[2] Xenophanes, 6 BCE.

[3] My argument is that the underlying metaphor for the mind or cognising subject is that of an organism undergoing evolution, patterned after Darwin's theory, with its central concept of the 'survival of the fitter' (Ernest, 1995).

scientific cultures (interpretations and interactions).

Other important and related issues have been the concepts of separate (objective) and connected (experiential) reasoning; the introduction of critical constructivism in balancing technical and practical interests[4] with an emancipative interest and ethic of care (Taylor and Campbell-Williams, 1998; Dawson and Taylor, 1997), and more recently the issue of learner empowerment – mathematical, social and epistemological – in mathematics education (Ernest, 2002). It is against these issues and the more parochial, yet symptomatic issues of academic integrity, student work ethic and motivation, English (I prefer the term literacy) across the curriculum, and my own philosophy of continuous (personal, professional and institutional) improvement (Deming, 1986), that I make the following proposal.

The proposal

The Trigonometry Unit of the Foundation Mathematics Pre-calculus II course at The Petroleum Institute, United Arab Emirates (UAE), has always been problematic. Traditionally scheduled at the end of the course, trigonometry is often abridged due to time constraints. While the pre-calculus courses focus on mathematical modelling and problem solving, the trigonometry section is usually more of an algorithm (symbolic manipulation) and skills unit which prepares students for the calculus courses that follow in the undergraduate programme.

Trigonometry is a unit which students enjoy doing. There are many reasons for this, including: (i) it is something the students have already seen in secondary school and recall easily, (ii) the terminology[5] is largely the same in English and Arabic, so those students with poor EFL[6] skills or non-English language backgrounds are not as disadvantaged as in other units, (iii) the content involved is problematic, complex (multiple solution pathways) and contextual, and (iv) it is not unusual for teachers to expect and encourage student risk-taking, collaboration and consultation owing to the 'complexities' sometimes encountered.

It is the last point that I will address first. It is part of the (student) culture in the UAE to collaborate. Students are reluctant to refuse assistance to anyone in need. In particular, the camaraderie of learning in a foreign language, sharing the related difficulties of comprehension of foreign texts[7] and idioms in a culture that was traditionally oral, anneals student resolve and makes it natural and ethical for stronger students to support those with difficulties. From a typically Western viewpoint, this collaboration goes to lengths considered unacceptable by staff. Indeed, students need to be supervised closely in classroom tests and formal examinations, lest they seek help and answers from their peers. In light of what appears to be a lack of awareness of the degree

[4]Certain fundamental human cognitive interests – technical, practical, emancipatory – are crucial to the way in which human knowledge is constituted (Jurgen Habermas, 1972).

[5]Brian Bielenberg from United Arab Emirates University has indicated from his research that average student vocabulary is more deficient for general educational terms (such as justify, interpret,..) than for specialist jargon (such as sine, cosine, etc).

[6]English as a Foreign Language.

[7]At a recent workshop on teaching EFL across the curriculum a respected colleague gave the following figures (from research). It takes 2 years (on average) of immersion for an average student to learn to speak English. It takes 7 years for the same student to learn to read (comprehend) and write in English – something most teachers, including myself, were unaware of.

of difficulty encountered by students (see footnote 7), teaching staff may be guilty of inadvertently overloading the students, both physically and conceptually, and consequently exacerbating this situation.

In addition, while the difference between collaboration and copying may appear clear-cut to most teachers, when applied to an endless stream of problems, assignments, and other deadlines, demarcation along the ‘collaboration–copying’ continuum becomes a ‘grey area’ which students often refer to as ‘consultation’. Whether consultation is to be encouraged or not appears to depend on the individual teacher, the ability levels of the students involved, and of course the quantity and the complexity[8] of the work involved. With trends in Western mathematical education going from the behaviouralist’s repetition of skills through drill to the constructivist’s fewer (quality) problems of greater complexity, it may be time we in the Middle East considered a similar move.

The Trigonometry Unit lends itself to such a move. With students who have such a rich and varied background in the subject it is easy to establish collaborative groups and behaviour. The nature of the textbook in current use[9] is such that student referral is encouraged rather than a lock-step journey from chapter to chapter. My proposal is simple – provide students with an assessable, stand alone, unit of work which consists of selected information, examples, and problems from the trigonometry chapters of the course textbook, supplemented by teacher produced handouts and worksheets. Each of these selected components is designed to: (i) ‘fast track’ them through certain sections of the textbook, and (ii) supplement the textbook activities by providing problems which are contextual, challenging, and act as sources (examples) of cognitive conflict. This unit of work would be administered (delivered, supported and assessed) according to constructivist principles and guidelines.

Firstly, to develop an awareness of prior student constructions (knowledge, skills, strategies, beliefs and values) students would sit a ‘baseline’ diagnostic test (Duit, Treagust and Mansfield, 1996) in trigonometry.[10] The time used to administer and mark this test would be minimal, would give teachers better understanding of which students need (peer or individual, language or mathematical) assistance, and help fine tune delivery of the curriculum in general. To test students further for conceptual understanding and connectedness (of trigonometric ideas and applications, internally, and with wider life-world concepts and applications), a ‘concept map’ is the preferred assessment instrument. To reiterate Novak (1996), ‘concept maps are useful in a variety of applications, including facilitation of meaningful learning, design of instructional materials, identification of misconceptions or alternative conceptions, evaluation of learning, facilitation of cooperative learning, and encouragement of teachers and students to understand the constructed nature of knowledge’.

In our case it is pretty much all of the above. Administering a concept map at this early stage gives an authentic idea of the students’ initial ‘picture’ of trigonometry and in particular where he or she makes the connections between concepts. As a forma-

[8] Complexity in this case refers to both the linguistic complexity and the mathematical complexity.

[9] *A graphical approach to pre-calculus* (Hornsby, Lial and Rockswold, 2003).

[10] My colleague at The Petroleum Institute, Mr Michael Giblin, has as part of his Masters in Mathematics Education coursework, developed a 30 minute test which tests student’s vocabulary and understanding of Trigonometry, which could be adapted for this unit of work.

tive instrument, comparing maps or 'consulting' with peers enables students to modify and broaden their initial connections and areas of understanding. For the teacher, the map is invaluable for locating blind spots and broken connections which can then be remedied as part of instructional support. For the student, whole sections of content may be pinpointed for independent revision or collaborative remediation. It is further recommended that the concept map be used as an organisational tool, being maintained and upgraded over the life of the unit, as students develop a greater understanding of the topic and make more connections between concepts. Finally, a concept map of either the whole unit or one of its 'component areas' can be regarded as a powerful and authentic summative assessment tool. Applied in tandem with 'standard' trigonometric application problems, a concept map gives a broader 'picture' of each student's understanding of trigonometry and of the relevance of its applications.

In addition to optimising a broad range of resources (peer tutors, mentors, collaborators), delivering this unit in a collaborative mode enables the teacher to spend more time with individual students for purposes of remediation, consultation, and determination and analysis of student beliefs, values and preferred strategies. Biddulph and Osborne (1984) note that, 'alternative frameworks for concepts in science and mathematics provide important information about students existing knowledge. Listening and acknowledging these ideas is important. A number of effective teaching and learning approaches have been developed to work from existing concepts by generating new ideas from them'. This is not to say that the teacher would completely hand over time management to the students. While this is partially true and in the spirit of learner empowerment, it is intended that students would be given the unit of work with pre-established deadlines. In addition, the classroom teacher would macro-manage the unit by introducing sections of work or support materials at pre-determined times and in accordance to student requirements.

While the content of this unit would mainly be derived from its traditional source, namely the course textbook, it is worth noting that in an EFL environment, large numbers of the exercises may be inappropriate due to language considerations. Application questions that are designed to develop discrimination and analysis in native English speaking students can be confusing, de-motivating and irrelevant for a foreign language student. Such students require questions which are relevant to their own ethnic (Arabic) and professional (Engineering) cultures, and secondly, provide linguistic support or scaffolding to assist them in comprehending the problem at hand. Such scaffolding can be provided through 'duality'. By this I mean information is delivered in a dual context, either through text and symbols, text and diagrams, or in other combinations. It is necessary for teachers to adapt some of these textbook activities or develop activities of their own[11] to provide linguistic and contextual support and improve 'comprehensibility' on behalf of students seeking greater understanding. In addition to improving comprehensibility of questions, it is also desirable for teachers to facilitate incidents of cognitive conflict to precipitate instances of conflict resolution, assimilation and accommodation.

It is the constructivist experience that instances of genuine learning (construction) occur in effort to resolve cognitive conflict (challenges to pre-conceived ideas, beliefs and values) and accommodate new ones. Speaking from personal experience, this is

[11] Teachers already have their own (tailor made) resources to supplement the Trigonometry Unit.

more likely to occur in a problem-solving situation than a rote learning one, or even when observing teacher demonstrations. Because of the distorting influences of learning in a foreign language, the stimuli provided in conventional texts may be obscure and overlooked, and teachers are advised to develop problems of this nature with language constraints in mind. One excellent way of doing this is to provide instances in which the students' intuitive solutions (Goldberg and Bendall, 1996) or their traditional and trusted, in our case algorithmic, solutions are contradicted by clearly observable graphical solutions (see Appendix A). Another useful method is to provide instances where student's solutions contradict their real world common sense understandings that require further explanation or interpretation (see Appendix B). It is my belief that the materials and expertise required for development and delivery of such content matter are already available.

Finally, it is my opinion that the assessment of a unit of work such as this should be ongoing and formative. Students would be 'marked' according to the number of designated questions they had completed over the duration of the course, regardless of their source of solution. They would also be marked by the teacher based on the teachers (discretional) observation of their performance in learning activities, Finally, to meet student expectations and to prepare students for more formal examinations, they would be tested. The nature of the testing instrument could vary from a traditional style test to giving students individual or unique questions such as a concept map plus one 'standard' question taken from 'somewhere' else in the unit.

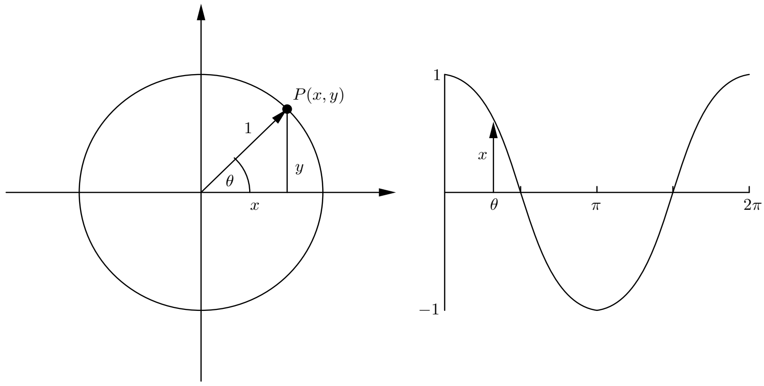
Conclusion

Graduates from the tertiary sector in the UAE require more than a 'collection' of memorised facts and processes. Destined to fill leadership roles, both professionally and culturally, many will assume the unofficial tag of 'expert' in the eyes of those under their leadership. To fulfill their destiny they must think critically and connectedly. Individually, and as part of a team, they must judiciously select appropriate technologies – modelling techniques and problem-solving strategies – to solve a variety of abstract and practical problems, and in doing so, connect an array of disparate concepts. They must interpret data and results, and communicate their solutions clearly, concisely, and accurately to a technical, real-world audience. They must be aware of the strengths and the weaknesses of their methods, including the shortcomings and limitations of the Western scientific method. As custodians of their own culture, they must ensure that this culture stands side by side (in significance and purpose) with the scientific culture of their training. In short, they must be empowered to think and act critically within the context of their own daily and professional lives. Such expertise is the product of experience (Polkinghorne, 2002). Black-box thinking with its psychometric neatness and illusion of standardised testing and analogous marks is a closed and self-perpetuating system. Its exclusion of experiential learning is a major flaw which has encouraged the adoption of constructivist practices in teaching and learning in its place.

Appendices

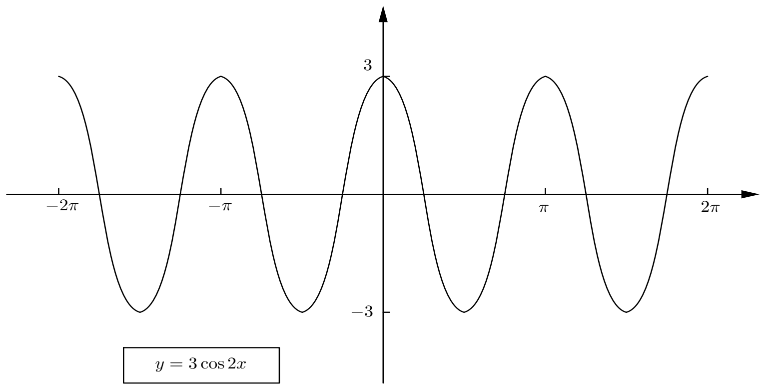
A. Linguistic scaffolding

The cosine curve



The diagram is given to students who also watch a simulation[12] and read a textual interpretation.

B. Cognitive conflict



(i) Amplitude, $|a| =$ ____________________

(ii) Period, $T =$ ____________________

(iii) Vertical shift, $d =$ ____________________

(iv) Locate the zeroes on $[-\pi, \pi]$ ____________________

[12] Available at: `http://curvebank.calstatela.edu/unit/unit.htm`

The graphical solution (number of zeros) disagrees with solutions reached using the traditional or preferred symbolic (analytical) solution. To resolve this conflict, students must adopt a new and broader solution strategy. In doing so they are: (i) more receptive to suggested approaches, and (ii) tend to learn and revise the prerequisite knowledge to a greater depth of understanding.

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A case study of online assessment for basic mathematics to motivate learners and enhance learning

Pádraig Hyland

Higher Colleges of Technology, Abu Dhabi Women's College, Abu Dhabi, United Arab Emirates

Abstract

This study explores ways that online assessment motivates learners and enhances learning. A case study of online assessment was carried out in a large third-level institution in the Middle East. Students studying a basic mathematics course completed a questionnaire and took part in interviews after using online assessments in independent study time. Results show that students put considerable effort into online assessments and used the online feedback provided to enhance their understanding. A motivational model for online assessment is presented that makes recommendations for the beginning, middle, and end of the learning process.

Introduction

Most of the existing computer-based learning packages have online assessment facilities to create, distribute and automatically mark assessment tasks. This is definitely an attractive feature for teachers as it promises a more efficient process, greater feedback and automated student assessment recording. However, some educators fear that the technology is artificially driving the usage of online assessment.

Review of the literature

Online assessment is fast becoming a significant part of online learning and there is an increasing amount of literature and research available to show this. However, what evidence is available from current research to show how this assessment motivates learners and enhances learning? Current literature identifies certain conditions of assessment that enhance student learning. They can be grouped into the three main areas of student effort, feedback, and student response.

Student effort – The influence of assessment on the volume, focus and quality of studying

There should be sufficient assessed tasks in a course and they must capture sufficient study time. This is based on Chickering and Gamson's (1987) 'time on task' principle: if students do not spend the time on something, they will not learn it. Assessment tasks

should ensure that students' time and efforts are normally directed at the most important aspects of the course. These assessments should be frequent so a student's efforts are distributed evenly across the course. The assessments should engage students with appropriate types of learning. Many students will not engage in 'deep learning' unless these high level demands are made in the assessment (Scouler and Prosser, 1994). Assessment should convey high expectations by challenging students to set high goals. Chickering and Gamson (1987) and Ramsden and Entwhistle (1981) have identified 'clear goals and standards' as a crucial factor in how assessment design affects the extent to which students take a deep approach to learning. Allan (1996) has reported that the introduction of learning outcomes in university courses has increased the proportion of students who see learning as involving understanding.

Feedback – Its influence on learning

Conventionally, feedback is conceptualised as an issue of correction of errors or acknowledgement of results in relation to learning itself. Knowing what you know and do not know focuses learning. Students need appropriate feedback on performance to benefit from courses (Chickering and Gamson, 1987). Sufficient feedback must be provided during online formative assessment. This feedback needs to be quite regular and in small chunks if it is to support learning across a whole course. Moshinskie (2001) suggests that feedback should be tied to the learner's performance level rather than to scores on assignments. This way, it can begin to foster reflection on performance (Freeman and Lewis, 1998). Cook (2001) reported that students' final marks were closely related to the frequency of online assessment methods used. The frequency and speed of response of such feedback may compensate for its relatively poor quality and lack of individualisation. The focus of the feedback that students receive is also important. Wootton (2002) suggests that assessment systems should exist to encourage learning, and feedback should tell students where they have gone wrong and what they can do about it. The feedback to students should be timely in that it is received by students while it still matters to them and in time for them to pay attention to further learning or receive further assistance. This is highlighted by Chickering and Gamson (1987). If student feedback is delayed, they will have moved on to new content and, as a result, it is unlikely that the feedback will promote additional learning. Feedback to students must be relevant to the purpose of the assignment and to its criteria for success (Bonk, 2002). Opportunities to provide feedback at multiple stages during an ongoing project can re-orient student effort in appropriate ways (Carless, 2002).

Student response to feedback – How it is used?

A number of studies have described what students do when they receive their feedback. Many cases have been reported where students glance at the marks on the bottom and then throw it away without looking at the feedback. Crooks (1988) has found that where marks on mid-semester assessments count significantly towards final assessment, students pay little attention to accompanying feedback. Hodges (2004) also found that students were most likely to look at marks rather than feedback on assignments. However, these students liked to see the feedback, but mostly as an assurance that the assessment had been read carefully and marked fairly. A number of suggestions have been made by researchers to engage students with feedback. Dochy, Segers and Sluijsmans (1999) suggest that assessments should be self-assessed so that students pay attention

to whether teachers' views correspond to their own. This has been shown to increase student performance. Cooper (2000) has reported how using two-stage assignments with feedback on the first stage helps students improve, while the second submission mark was found to improve almost all students' performance. The impact on students' future learning is also a concern. Although feedback may accurately correct errors, a number have already been mentioned that can explain why students do not change the way they attempt subsequent assessments. Ding (1998) suggests that even if students read feedback, they do little with it, while in contrast, Brookheart (2001) found that successful students use both marks and feedback actively to self-assess. Perhaps teaching students to monitor their own performance is the ultimate goal of feedback (Sadler, 1989). Research on the impact of 'classroom assessment' stresses the impact on the ability of students to gain control of their own learning and the development of 'meta-cognition' (Steadman, 1998).

Certain conditions of assessment have been identified that support student learning. They can be grouped into three main areas – student effort, feedback, and student response. Experienced teachers know that without the proper motivation for students to engage in a learning experience, the otherwise best designed experiences will be unsuccessful (Hodges, 2004). Therefore, the construct of motivation as it relates to learning will be addressed, some general background information will be discussed, two instructional design models for motivation will be described, and examples of best practice for web-based learning will be supplied.

Motivation theory

There does not seem to be a standard definition of motivation. It has been recently defined as the attention and effort to complete a learning task and then apply the new material to the work site (Moshinskie, 2001). Bandura (1997) identifies three forms of motivation around which different theories have been built, namely attribution, expectancy value, and goal theory. Attribution theory is concerned with how a learner explains successes and failures. A learner may attribute the success or failure on an assignment to oneself, or to external reasons. Instruction should make an effort to help learners attribute their learning outcomes to the controllable but unstable construct of effort. Learners will have no motivation to participate in a learning experience without the belief that change is possible. The general notion of expectancy-value theory is that learners expect certain outcomes from behaviours and the more valued the outcome, the more likely someone is to perform the necessary behaviour. Goal theory assumes that establishing goals to be obtained motivates behaviour. Goals may be performance-based or learning-based but are not enough on their own. Learners must be able to gauge their progress towards success by receiving some measure of progress. Therefore, meaningful feedback plays an important role in goal theory.

One common element that exists throughout all three theories is the self-efficacy involved with motivation. Perceived self-efficacy refers to the belief in one's capabilities to organise and execute the courses of action required to produce given attainments (Bandura, 1997). In attribution theory, students with heightened beliefs of personal efficacy as a result of attributing success to ability will achieve well in the future. In expectancy-value theory, students who achieve success in a particular learning task, increase their self-efficacy and thus the likelihood of repeating the task successfully in the future is increased. In goal theory, one's perceived abilities will dictate the goals an

individual will set and how the experiences in achieving the goals will contribute to his or her beliefs of self-efficacy.

Motivational design models for online learning

Wlodkowski's *Time Continuum Model* (1988) of motivation identifies three critical periods in the learning process where motivation is most important: the beginning, the middle, and the end of the learning process. Attitudes and needs are important at the beginning. The designer should consider how the instruction will meet the needs of the learners and how a positive learner attitude can be developed. Clear objectives should be stated, assessments should be related to them and, where possible, be based on experiences familiar to the learners (Wlodkowski, 1985). During the learning experience, Wlodkowski's primary strategy is to make the learning experience as personalised and as relevant to the learner as possible by encouraging learner participation, varying presentation styles, and using different modes of instruction. Finally, at the end of the learning process, frequent feedback and the communication of learner progress are the main methods for developing confidence in learners.

The ARCS (attention, relevance, confidence and satisfaction) model (Keller, 1987) is a method for systematically designing motivational strategies into instructional materials. It works under the assumption that learners will be motivated if they feel they can be successful and that there is value in their learning. Keller (1987) lists several strategies for each of the categories mentioned, including using a variety of delivery methods to help sustain attention. Linking assessment to course goals and stating how the instruction relates to learners helps keep the learning relevant. Attributing success to effort and allowing students to become independent learners instill confidence, while reinforcement, attention, and feedback promote student satisfaction.

It is clear that both the Time Continuum Model and the ARCS model are similar and a deliberate use of either model would produce instructional experiences that would be similar where motivation is concerned (Hodges, 2004).

Motivational techniques successfully used in web-based settings

Relevance is by far the most reported successful motivator. Bonk (2002), Hardre (2001), Moshinskie (2001) and Reeves (2001) all found that materials relevant to the learner were successful motivators for learning. Assessments that were described as 'authentic tasks' were a common course component. Case studies and reflections on work experiences were examples of these strategies that ensured relevance (Hodges, 2004). In addition to relevance, Bonk (2002), Harde (2001) and Moshinskie (2001) list meaningful feedback as an important element of the e-learning experience. Moshinskie (2001) along with Song and Keller (2001) suggest using motivationally adaptive feedback. This feedback should be tied more to the specific learner's performance level rather than to simple milestones or scores on assignments. The importance of feedback and reflection upon performance has also been emphasised by Felder and others (Felder, 1993; Freeman and Lewis, 1998). They have shown that not only is feedback important in formative assessment, but also for motivation and engagement of learners. Other motivational practices include the forming of learning communities online, varied presentation formats (Moshinskie, 2001) and a simple and easily understood navigation system within the learning experience (Hardre, 2001; Reeves, 2001). There is a growing body of research that details student attitudes to the design of online assessment.

Leung (2003) suggests that some desirable features of an online assessment system include the ability to move between questions, the necessity to be able to check all answers before submission, and the ability to see one question per screen.

Research study

Design

A case study methodology was chosen as it is an ideal methodology when a holistic, in-depth, investigation is needed (Feagin, Orum and Sjoberg, 1991). Case studies are designed to bring out the details from the viewpoint of the participants by using multiple sources of data. This case study focused on how computer aided assessment motivated and enhanced learning.

Research sample

The research sample for this study consisted of one hundred first-year Diploma students. The students were all female aged between eighteen and twenty-three. In their first year, they study basic English, Mathematics, Computing and Information skills. These skills create a foundation for the students' choices in the second and third year of the diploma where they specialise in Business, Computing, or Communication Technology. Students were introduced to the online assessment activities during a mathematics lesson. They were encouraged to use the assessments as an independent learning resource to reinforce the concepts that they needed to review.

A description of the online assessment materials

The online assessment materials were designed following Wlodkowski's Time Continuum Model (Wlodkowski, 1985) where motivational strategies are incorporated into the beginning, middle, and end of the learning process. This instructional design method had the four following steps: define, design, develop and evaluate. Firstly, the aims and objectives for the online assessment were defined and the content that the students had most difficulty with in the past was selected. This was done to ensure that the material was relevant for the students, as this has been highlighted as an important motivating factor in the design of online assessment (Hodges, 2004). In the design phase of the development, there were a number of factors that had to be considered. The navigation system had to be clear and easy to follow. There were links on each page that were consistently placed and allowed users to choose their path through the unit. The unit was divided into four lessons with each lesson following a similar format. An introductory page outlined the learning goals; annotated examples followed. Interactive exercises allowed students to practice the concepts and a revision page summed up the main teaching points. Another design consideration was the use of varied presentation formats. This is listed as a practice for motivating students (Hodges, 2004). In this unit, students had to complete multiple-choice questions, short answer questions, crosswords and matching exercises. Instruction was text based but an interactive flash movie was used to illustrate am and pm times. The final consideration in this part of the design process was the provision of feedback. Feedback has been shown to be an important element in the e-learning experience (Bonk, 2002; Hardre, 2001; Moshinskie, 2001). It should be frequent, timely, detailed, performance related, and related to the learning outcomes (Hodges, 2004). In this unit, feedback was provided for all ques-

tions that the students attempted. The feedback either confirmed that their answer was correct or explained why the answer entered was incorrect. During the third step in the instructional design process the instructional materials were developed and uploaded to the WebCT server. The interactive quizzes were created using ‘Hotpotatoes’ software and were saved as html pages. They were hyperlinked to other html pages that were structured as described in the design section above. The final step in the instructional design process was evaluation. The online assessment materials were piloted using a similar group of students that would not be taking part in this study. They were asked to complete a short survey about the design and implementation of the online assessments.

Results and discussion

Student effort – The influence of assessment on the volume, focus and quality of studying

According to Chickering and Gamson’s ‘Time on task’ principle, students should give sufficient time to their learning and this time should be evenly distributed across the course. Questionnaire results revealed that 63 per cent of students were regularly using the online assessments while 16 per cent were not. Questionnaire data also revealed that 95 per cent of the diploma students felt that there was a strong link between the time spent on assessment tasks and their achievement in the course. Interview data confirmed that 75 per cent of students were willing to spend the necessary time to prepare well for assessments. This shows the importance of properly constructed assessments that focus students on the most important parts of the course. Otherwise, they could spend many unproductive hours completing irrelevant assessed tasks (Kember, Ng, Tse, Wong and Pomfret, 1996). According to Chickering and Gamson (1987) and Scouler and Prosser (1994), students should focus on productive learning and high expectations that encourage deep learning should be communicated and encouraged through assessments. Questionnaire data revealed that 84 per cent of students found online assessments challenging and that 80 per cent of students felt they learnt more by completing them when compared to completing other course materials. During interviews, students gave different reasons for the popularity and usefulness of the online assessments. Fifty-five per cent suggested that after reading the learning outcomes and completing the assessments, it was clear what they needed to study to improve their understanding. This supports Allan’s (1996) findings where the introduction of learning outcomes helps students see learning as involving understanding.

Feedback – Its influence on learning

According to Chickering and Gamson (1987), students need appropriate feedback on performance without delay to benefit from courses. Questionnaire data revealed that 88 per cent of students receive plenty of feedback in a timely fashion while 95 per cent like to receive immediate scores from the assessments. Ninety-three per cent of students felt that the feedback helped them understand concepts better. Student interviews revealed that 65 per cent of students liked to receive feedback in small chunks. This was also reported in research by Wootton (2002) who suggests that feedback should tell students where they have gone wrong and what they could do about it. Student interviews also showed that 75 per cent of students were aware of their progress after completing the

online assessments. Sixty per cent kept a note of the scores that they received and tried to improve their scores in subsequent assessments.

Student response to feedback – How it is used?

According to Brookheart (2001), successful students use both marks and feedback to actively self-assess. This should be the ultimate goal of feedback (Sadler, 1989). Eighty-seven per cent of students reported instantly understanding their mistakes after reading the online feedback. This was explored in more detail during student interviews where students were asked for their next step after recognising their mistakes. Sixty per cent of students said that they correctly answered subsequent questions using only the feedback that they had received. However student questionnaires showed that 30 per cent of students did not understand some of the online feedback and 29 per cent did not understand their mistakes after reading the feedback. This was further examined during student interviews where a number of possible reasons were uncovered. Thirty per cent suggested that their English skills were not good enough to understand the feedback in a way that would 'teach' them, while 50 per cent suggested that they preferred to have the teacher explain something that they could not understand rather than have to work it out for themselves. Questionnaire data revealed that 74 per cent of students revised course material after reading the online feedback. Student interviews examined this in greater detail and found that students were selective on the material that they revised. Thirty per cent said that they revised the questions from their notes that matched the questions in the online assessments as they felt that they were 'important'. Fifty-five per cent said that they only revised the questions that they answered incorrectly during the online assessments. This would seem to indicate that these students were beginning to gain control of their own learning and develop mega-cognition (Steadman, 1998).

How motivating do students find online assessments?

The online assessment materials were designed following Wlodkowski's Time Continuum Model (Wlodkowski, 1985) where motivational strategies are incorporated into the beginning, middle, and end of the learning process.

Motivational strategies at the beginning of the learning process

Interviews revealed that 75 per cent of students were clear about what they were going to learn from the online assessments after clicking on the opening page. This was reported in research by Wlodkowski (1985) who found that clear objectives should be stated and the assessments should be related to them. When asked about the suitability of material chosen for the online assessments, 85 per cent said that it helped build their understanding of the concepts presented and that it was an area that they needed opportunity to study. Student questionnaires triangulated with this finding as 77 per cent said that the online exercises were relevant. This was reported by Bonk (2002) and Hardre (2001) as by far the most reported successful motivator.

Motivational strategies in the middle of the learning process

When examining motivational strategies incorporated into the middle of the learning process, questionnaires revealed that 81 per cent of students found the online assessments clear and easy to follow while 93 per cent of students thought that the review page helped them remember important teaching points at the end of the lesson. This motivating practice was presented in research by Hodges in 2004 as an important factor in the design of online assessment. Interview transcripts showed that 85 per cent

of students used the online assessments during their independent study time. They reported that they liked using the different question types that were included in exercises and said that this made the exercises more interesting. This motivation practice was identified in research by Hodges (2004). Students who preferred online assessment to paper-based versions liked the ability to navigate from question to question easily (40 per cent) and mentioned that the provision of instant feedback (45 per cent) was also important to them. These findings were also presented in separate research by Moshinskie, Hardre and Reeves (2001) where simple navigation and instant feedback were found to be important motivational practices. Of the students that preferred the paper based assessments, 60 per cent said they liked to be able to write down their calculations when answering questions. Additionally, 20 per cent said they found it easier to read the questions from a paper rather than a screen.

Motivational strategies at the end of the learning process

When examining motivational strategies incorporated into the end of the learning process, frequent feedback and the communication of learner progress are the main strategies used (Wlodkowski, 1985). Eighty-eight per cent of students indicated that feedback was frequently provided in sufficient detail while it was still relevant and useful to them. Seventy-five per cent were aware of their level of performance after reading the feedback and liked to receive it in small chunks when it was relevant to them. Students also indicated that feedback engaged them in different ways to improve their understanding. It encouraged 74 per cent to revise previously covered material which influenced their future learning and 55 per cent of these cases seemed to indicate that students were beginning to control their own learning. Interviews examined this and found that 40 per cent of students wanted links to other web-based learning opportunities, while 35 per cent wanted to use links that referred them to extra examples in their textbooks.

Conclusions and recommendations

This paper has attempted to identify certain conditions of online assessment that enhance student learning. It examined students' efforts with online assessments. The study revealed that students regularly give time to their learning, even when there are no formal assessments planned and that this was essential for success. They spend extra time studying in preparation for assessments and do not confine their revision to materials being assessed. They find the online assessments challenging and feel that they help them build their understanding of the concepts being taught.

The study also examined the online feedback that students receive. It found that feedback is provided frequently and in sufficient detail to be useful while it is still relevant to learners. Students are aware of their level of performance after reading the feedback and like to receive it in small chunks to further aid in understanding.

We also examined students' responses to online feedback. It found that feedback engaged students in different ways to improve their understanding. It encouraged them to revise previously covered material which influenced their learning further and, in some cases, seemed to indicate that students were beginning to control their own learning. This study also found that some students prefer to ask teachers to revise something with them rather than use the online feedback to help them.

This study also looked at factors involved in the motivation of learners. A model of motivational online assessment is presented which is based on students' responses to the online assessments that were designed for this study. The design choices made were based on Wlodkowski's Time Continuum Model (Wlodkowski, 1985) where motivational strategies are incorporated into the different parts of the learning process.

At the beginning of the learning process the aims and objectives must be clearly stated and understood by students. The assessments must be related to these stated aims and objectives and should enhance students' understanding of the concepts being taught. The online assessments must be relevant to what the students are learning. The assessment schedule should ensure that students regularly give sufficient time to their learning.

During the middle of the learning process, the students use the online assessments. Their structure must be clear and easy to follow. It should be similar on all pages so that the user can work through the assessments in a controlled fashion. Different presentation methods that are not entirely text based should be incorporated to cater for students with different learning styles. A revision page at the end of the assessments helps students improve their understanding. When designing the assessment exercises, different question types should be used as this makes the exercises more interesting. It should also be possible to navigate from question to question easily before submitting them for marking.

During the end of the learning process, frequent feedback should be provided to students. It should be sufficiently detailed to be useful to them and should make students aware of their level of performance. Feedback should engage students in improving their understanding by providing links to other online and offline learning resources. Feedback should be provided in small chunks if it is to support learning across a whole course. The ultimate goal for the provision of feedback should be to teach students to monitor their own performance.

These findings offer suggestions from students who have used online assessment systems designed to motivate learners and enhance learning. If implemented, the model presented should result in the improvement of online assessment systems which in turn could aid efforts to build a richer overall teaching and learning environment. This is just one way in which information and communication technologies can act as a catalyst for teachers and educators to revisit fundamental educative principles.

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Characteristics of appropriate use of technology in teaching and assessment

J. V. Marc Corbeil

Higher Colleges of Technology, Al Ain Women's College, Al Ain, United Arab Emirates

Abstract

Moore's law (technological power doubles every eighteen months) suggests that training for one particular type of technology will have limited effect as compared to the rapid development of technology. The availability of advanced technology to teachers in the classroom is increasing faster than the ability of many teachers to cope and adapt to new technologies, creating a digital divide between classrooms and between institutions. As many teachers lack formal training in the use of technology, few have had extended contact with new technology, and support for innovation is usually not systematic or practical. Thus, it is not surprising to witness inappropriate use of technology in some classrooms. This paper suggests some basic characteristics of the appropriate use of technology, bringing to light some of the major issues involved in bringing technology into the classroom and perhaps providing a contribution to the development of policies.

Introduction: Should we teach with technology?

'The true way of [mathematical] art is not by instruments, but by demonstration: and that it is a preposterous course of artists, to make their schollers only doers of tricks, as it were juglers: to the despite of art, losse of precious time, and betraying of willing and industrious wits, unto ignorance, and idlenesse. That the use of instruments is indeed excellent, if a man be an artist but contemptible, being set and opposed to art' (Oughtred as quoted in Forster, 2005). That we, as educators, can still ask this question I believe shows a maturity not often found in our contemporary society. The shadow of big technology and big business is always upon us. For some, asking such a question is foolishness and demonstrates how out of touch education is with the real world. Recently, US Secretary of Education Ron Paige attempted to sum up this view, saying that 'education is the only business still debating the usefulness of technology. Schools remain unchanged for the most part, despite numerous reforms and increased investments in computers and networks' (Paige, 2005).

Perhaps the reason technology is not spilling out of school doors is because educators know that 'simply using instructional technology does not guarantee successful

student learning or better educational outcomes' (Division of Instructional Innovation and Assessment (DIIA), 2005). In short, education debates technology use because we are not in the business of making cars. We are teaching people, a process some of us believe is slightly more complicated than manufacturing.

While it is true that some countries lag far behind in adopting new technology in the classroom (Oldknow, 1997; Monaghan and Rodd, 2002), most countries are placing cutting edge technology in the hands of students far faster than businesses place cutting edge technology into the hands of their employees (Associate Press, 2005). Educators do so because technology represents a potential to do things differently, and it provides important tools to help learners to learn. We choose technology because we think it helps us reach a particular learning goal better or faster. Thus, the first characteristic of the appropriate use of technology is a teacher who uses technology as a tool to achieve a particular goal or process.

When should we use technology?

Technology generally provides at least two major affordances: representation and communication (Kaput, 2004). The classroom contains the potential for different learning styles, visual, auditory, tactile and kinaesthetic. Gardner (1983) states that 'experiential learning' should be considered in order to offer alternatives and opportunities necessary for success. Teachers should provide opportunities for learning via alternative learning styles, but doing so is often very difficult. Even if the majority of students were auditory, the learning style corresponding to the traditional classroom, teaching only in one style is grossly insufficient. Auditory overloading, especially in second or foreign language situations, is certain to occur in such classrooms as the auditory memory pathways are overworked and crammed with traffic (Owensby and Kolodner, 2002).

Popping up pictures and sounds may help to open alternative pathways for memory mapping. Linked memory related to particular sights, sounds or smells is a well-documented phenomena (Gottfried, 2003; Engen and Ross, 1973). Using visual components in a lecture or encouraging tactile and kinaesthetic experiences with hands on computer-based programs or modelling may enhance the development of representation and communication. At the very least, the lecture will be slightly more interesting and keep student attention longer.

The second characteristic is a teacher who uses technology to enhance representation and/or communication, providing alternative learning styles and possible improvement of memory mapping.

How should we use technology?

Moore's law states that technological power doubles every eighteen months and most institutions upgrade on a three- to five-year schedule. This means that the availability of new technology to the teacher in the classroom is increasing faster than the ability of many teachers to cope. Many teachers lack any formal training in the use of technology and few have had extended contact with new technology (Corbeil and Brown, 2004; Oldknow, 1997; Monaghan and Rodd, 2002).

Technology such as Graphics Display Calculators (GDCs) or Computer Algebra System enabled (CASe) devices evolve even faster than computers and require very specific training that may rapidly become obsolete. Training new teachers for a specific computer program that may become obsolete before the end of teacher training is no better. It seems likely that a newly-trained teacher will face some kind of new technology in his or her very first year of teaching (Corbeil and Brown, 2004, Monaghan and Rodd, 2002). Add to this the heightened set of expectations coming from administrators, parents and the community at large for teachers to make use of technology in the classroom while at the same time improving outcomes. Given the limitations and costs, is it fair to set expectations of teachers so high and how do we make training decisions for teachers?

It seems that a better approach might be to give teachers some kind of grounding for the next level of technology rather than only specific skills in current technology. The critical skills that teachers need are the ones that allow them to transfer themselves between micro-worlds. Teachers need to learn how to evaluate how technology makes their teaching better (or possible in an alternative learning style) and how to improve the enhancement of representations and communication. This requires a grounding in the understanding of the process involved in learning generally, and learning with technology specifically, not just stand alone training in one piece of software or product but the theory of using technology in teaching in general. For example, one could package theory around training in a specific cutting edge technology as an in-service course.

The third characteristic of the appropriate use of technology is a teacher who has been trained in the *theory* of using and evaluating technology, skills that can be transferred to the next evolution of technology (learning how to learn).

How do we assess the learning goal?

We know that technology is creating some major difficulties in assessment, and we know that unbalanced or inappropriate use of technology can seriously disadvantage some students (Corbeil and Brown, 2004). When assessing mathematics and science one has traditionally expected students 'to show enough of their work for readers to follow their line of reasoning' (College Board, 2003). But technology results in both students and teachers falling well short of what we traditionally have thought of as 'answers'. Consider the following example:

> Andrew has 200 dirhams. He buys five energy drinks at 20 dirhams each and one shirt which costs 22 dirhams. How much change should he receive from his initial 200 dirhams?
>
> A typical marking scheme is: $5 \times 20 = 100$, $1 \times 22 = 22$, $100 + 22 = 122$, so that $200 - 122 = 78$. Thus he receives 78 dirhams in change.
>
> Student answer: 78 dirhams. (i.e. no working).

A number of teachers have a hard time giving full marks to a solution that 'appears' to lack any support or demonstration. There is this nagging feeling that the student

must have cheated or that something fundamental is missing. In short, we judge a student's answer as a product outcome. But, the lack of work on examinations in today's computer or calculator world does not imply that work did not occur. Indeed, a very advanced level of thinking is likely to have occurred via a hand-held device.

In one line on the calculator,

$$200 - (5 \times 20 + 1 \times 22),$$

hit equals and, voilà, 78 magically appears! Students often understand and use technology far better than we do and it should not come as a surprise when they 'out-tech' us. Should we penalise for a lack of working when the student answered the question in a sophisticated technological manner?

It is true that students are over reliant on technology to do what we consider mental mathematics. The history of science and mathematics is full of these funny little examples of critical basic skills that disappear later on. For instance, the following type of problem was once routine in algebra examinations.

> On paper showing all your work (today's euphemism for no calculator), extract the cube root of 113 to four decimal places.
> The solution would require ten iterations of the modified Babylonian algorithm, with about thirty to thirty-five intermediate calculations.

The 'computational medium alters the growth of mathematical content, changes which content is important and for whom, changes the means by which it can be known, taught or learnt, changes the socio-cultural milieu in which teaching and learning occur and in which the institutions of education live, changes the relations between schooling and living . . . ' (Kaput, 1998). If true, does it make sense to maintain subject matter that is trivialised by technology or to award marks for machine answers? It seems obvious that teachers need to be very familiar with technology and identify when, where, and how students use it in the subject.

The fourth characteristic: If technology is introduced into teaching, then the subject and assessment must be adjusted to account for the difference in learning and, then, adjustments must be made to account for the changes that occur to the subject matter.

High stake assessment: Product versus process

We have an infatuation with learning as a product outcome and this may become a serious barrier to the appropriate use of technology (Rogers, 2003). If we wish to adopt new technologies and new ways of doing mathematics in schools then we first must recognise that high stakes assessment is one of the most significant influences on what and how we teach (Barnes, Clarke and Stephens, 2000; Corbeil and Brown, 2004). Time limitations and that final examination are realities of the game. We know it, and act accordingly as any other action would be irresponsible.

Recently, many educators have given some thought to alternative assessment models including project-based teaching and it is not surprising that teachers attempting to use technology in the classroom for the first time find themselves with the same sort of problems as those trying alternative assessment models: time constraints and product

outcome-based assessment. Alternatives bring down results and make all involved uncomfortable. The use of technology often does not result in measurable improvement of outcome, or may even have a negative result, especially when using pre-technology assessment models. Can the use of the Personal Digital Assistant (PDA), laptop, or Tablet PC be fairly evaluated within this structure? The question ‘tools or toys?’ quickly springs to mind and often requires an innovative approach.

Perhaps using product outcome is not a viable method of evaluating technology in education. A slight shift towards process outcomes can help alleviate some of the stress of using project- or technology-based teaching. Blenkin and Kelly (1981) suggest that we evaluate intellectual development and cognitive functioning rather than the quantities of knowledge absorbed or changes. Performance tasks that assess ‘processes rather than products’, ‘approached and planned by reference to the kinds of activities and experience that constitute’ the process of learning. Open-ended questions, for example, can illicit impressive demonstrations of subject material.

The introduction of GDCs and CASe devices in high-stakes examinations have had, so far, only a small impact on examination instruments and the main reaction has been to neutralise technology in examinations (Corbeil and Brown, 2004). Open-ended and device-active questions are only two among the many possible alternatives to traditional assessment but this rarely sees the light in mathematics examinations and is practically a non-starter in science subjects. Since assessment is mostly a reflection of institutional leadership, the current status of assessment represents very poor leadership indeed.

Examination boards need to find examiners who are experts and teach regularly with cutting edge technology. The fact is that we want students to demonstrate that they can use the calculator to get answers. Assessment must move away from a basis in the testing of rote manipulation and toward problems that probe an understanding of the fundamental concepts (College Board, 2003). We have plenty of practice with drill and answer, but sparse experience in determining actual subject understanding of a particular student. Perhaps tapping the process of learning a subject may result in a better understanding of this process and better schemata to improve the understanding.

Defining goals as process outcomes as the major feature of the assessment model is the fifth characteristic of the appropriate use of technology.

Who leads and supports teaching with technology development?

It is not surprising to witness inappropriate use of technology in some classrooms. The command from administrators is to use technology. Here the common thinking is ‘here it is, there is some training, now go away and get better results!’ This is the danger in taking a business model too far into education. In business, it is well know that computer technology traditionally has three almost equally costly parts: hardware, software and training. Failing to account for the cost of one of these will be tragic.

Education, at least the job of teaching, is not a business. In education, we need to add a fourth critical cost: multi-disciplinary, multi-level innovative support. Ask yourself, where does one find the expertise for technology use in my school? From IT? The purpose of IT in an institution is in the support of current and past technology, not development. It is unreasonable to ask them to go cutting edge when today’s problems are from yesterday’s hardware and software. Teachers are busy teaching and adminis-

trators are nervous about using tools that may have negative effects on results (again product outcomes). Examination boards are unlikely to point to any deficiencies in their examination schemes, even though we know that high-stakes examinations drive curriculum.

The innovations seem to come from the so-called ‘early adopter’ teachers. You can give technology to the early adopter types just like you would add plug and play devices on your computer; plug in and go. Late adopters, on the other hand, represent incompatible and literally unsupported devices. These teachers need serious hand-holding, in-classroom mentoring and organised support, someone who is there the first couple of times to show them where to plug in and how to turn on. Early adopters are usually tapped for help but availability is limited since they are teachers with busy teaching schedules, committees, and papers to mark. Left alone, this is an untapped and diminishing resource. In addition, early adopters are rarely trained in theory and may lack adequate preparation time to consistently use technology appropriately. Early adopters can easily lose sight of the learning goal and have little power to work towards changes in teaching styles and assessment throughout a programme.

The characteristics need to be fused. Leaders (trainers?) in appropriate use of technology need to be trained or experienced in the theory behind the use of technology so they can transfer these skills, as well as specific ones related to the technology at hand. Identifying, supporting and re-positioning these kinds of early adopters is necessary to improve the systematic relationships between users towards learning goals. The learning goals need to be reflected in the adoption of technology but also adaptation of the learning goals must occur as technology is introduced; all this while keeping in mind the process of learning and the importance of opportunities to learn in more than one learning style, interchanging, and active representations.

This relationship then needs to be borne out in the assessment instruments used (and general institutional goals) either by involving the leaders in the process of assessment directly or by making demands that examination bodies adjust assessment to take account of appropriate (but perhaps cutting edge) technology being used in the subject. This means providing support outside of the normal academic structure or creating specialist positions across departments and schools.

Thus, the final characteristic of the appropriate use of technology is an institution’s systematic attempt to fuse the basic characteristics into the general instructional principles and policy. Starting with the view of technology as a means to achieve a particular learning goal, work towards having teachers who use technology to enhance representation and learning alternatives, teachers with transferable skills and theory of teaching with technology. The institution should demonstrate systematic accounting of the interrelationship between use of technology, assessment and subject content using subject, assessment and instructional goals defined as process outcomes.

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Patterns in convolutions of two series

A. Umar,[1] B. Yushau[1] and B. M. Ghandi[2]

[1] *Department of Mathematical Sciences, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia*
[2] *Department of Information and Computer Sciences, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia*

Abstract

We introduce and discuss three kinds of convolutions of two series: additive, multiplicative and exponential convolutions. The first kind, though well-known, is not generally viewed as a convolution. The second is the usual convolution, while the third is perhaps new.

Introduction

Convolution of two functions is a concept that mathematics, engineering, and physical science students usually come to know in either their 200 or 300 level courses at university. A typical topic where this is seen is in Laplace transforms, where an integral of convolution of two functions is evaluated for some specific functions (Zill, 2000). Students get to know more of the power and application of convolution as they advance their studies in various fields such as physics, computer science, statistics, and engineering. As noted in the *Physics Daily* (2005), convolution and related operations are found in many applications of engineering and mathematics. Cited examples include:

- In *statistics*, a weighted moving average is a convolution. The probability distribution of the sum of two random variables is the convolution of each of their distributions.

- In *optics*, many kinds of 'blur' are described by convolutions. A shadow (e.g. the shadow on the table when you hold your hand between the table and a light source) is the convolution of the shape of the light source that is casting the shadow and the object whose shadow is being cast. An out-of-focus photograph is the convolution of the sharp image with the blur circle formed by the iris diaphragm.

- In *acoustics*, an echo is the convolution of the original sound with a function representing the various objects that are reflecting it.

- In *electrical engineering* and other disciplines, the output (response) of a (stationary, or time- or space-invariant) linear system is the convolution of the input (excitation) with the system's response to an impulse or Dirac delta function.
- In *time-resolved fluorescence spectroscopy*, the excitation signal can be treated as a chain of delta pulses, and the measured fluorescence is a sum of exponential decays from each delta pulse.
- In *physics*, wherever there is a linear system with a 'superposition' principle, a convolution operation makes an appearance.

In a recent article we have showed how, if restricted to series instead of more general functions, convolution could be introduced at the secondary level without much difficulty. Our aim in this paper is to introduce three different kinds of convolutions of two series by analogy with the natural pattern of basic arithmetic operations, namely those of addition, multiplication and exponentiation. A discussion of each follows its definition and some open problems are highlighted as well. From now on we shall refer to the convolution of two series, simply as a convolution.

Additive convolution

Let $S_1 = \sum_{i=1}^{n} a_i$ and $S_2 = \sum_{i=1}^{n} b_i$. Then the *additive convolution* series of S_1 and S_2 is defined as

$$\begin{aligned} A &= A(S_1, S_2) \\ &= \sum_{i=1}^{n}(a_i + b_{n+1-i}) \\ &= (a_1 + b_n) + (a_2 + b_{n-1}) + \ldots + (a_n + b_1) \\ &= \sum_{i=1}^{n} a_i + \sum_{i=1}^{n} b_{n+1-i} \\ &= \sum_{i=1}^{n} a_i + \sum_{j=1}^{n} b_j \quad (j = n + 1 - i) \\ &= S_1 + S_2. \end{aligned}$$

In general there does not seem to be any gain in this approach, and perhaps this is true. However, if $a_i = b_i$ (for all i), that is $S_1 = S_2$ and S_1 is a series in arithmetic progression (AP), then it leads to the well-known method for finding the sum of the first n natural numbers, and hence an alternative method for the sum of the first n terms of an AP series. To see this, let $S_1 = \sum_{i=1}^{n} i$. Then

$$\begin{aligned} A &= A(S_1, S_2) \\ &= \sum_{i=1}^{n}[i + (n + 1 - i)] \\ &= \sum_{i=1}^{n}(n + 1) \end{aligned}$$

$$\begin{aligned} &= n(n+1) \\ &= 2S_1. \end{aligned}$$

Hence the well-known result for the sum of the first n natural numbers of.

$$S_1 = \frac{n(n+1)}{2},$$

follows. Essentially, it was this pattern in convolution that Gauss discovered at the age of seven when his teacher, Büttner, and his assistant, Martin Bartels, challenged Gauss to sum the integers from 1 to 100, (see, e.g., Dunham, 1991, pp. 236–237).

Next, if $S_1 = \sum_{i=1}^{n}[a + (i-1)d]$, then

$$\begin{aligned} A &= A(S_1, S_2) \\ &= \sum_{i=1}^{n}([a + (i-1)d] + [a + (n-i)d]) \\ &= \sum_{i=1}^{n}[2a + (n-1)d] \\ &= n(2a + (n-1)d) \\ &= 2S_1. \end{aligned}$$

Hence, we have

$$S_1 = \frac{n}{2}(2a + (n-1)d).$$

Multiplicative convolution

Let $S_1 = \sum_{i=1}^{n} a_i$ and $S_2 = \sum_{i=1}^{n} b_i$. Then as in Umar, Yushau and Ghandi (2006), the *multiplicative convolution* or simply *convolution* of S_1 and S_2 is defined as

$$\begin{aligned} C &= C(S_1, S_2) \\ &= \sum_{i=1}^{n} a_i\, b_{n+1-i} \\ &= a_1 b_n + a_2 b_{n-1} + \ldots + a_n b_1. \end{aligned}$$

If $a_i = b_i$ (for all i), then $S_1 = S_2$. In this case we shall refer to C as the *self-convolution* of S_1. It is worth noting that the self-convolution of S_1 for a series in AP and a series in geometric progression (GP), the sum of the first n natural numbers and their square, has previously been discussed (Umar, Yushau and Ghandi, 2006).

The main results concerning series in AP and GP are:

Result 1

Let

$$\begin{aligned} S_1 &= a + (a+d) + (a+2d) + \ldots + (a + (n-1)d), \\ S_2 &= a' + (a' + d') + (a' + 2d') + \ldots + (a' + (n-1)d'), \end{aligned}$$

be two series in arithmetic progression. Then the sum of their convolution series is

$$C = naa' + (ad' + a'd)\binom{n}{2} + dd'\binom{n}{3}.$$

Result 2

Let

$$\begin{aligned} S_1 &= a + ar + ar^2 + \ldots + ar^{n-1}, \\ S_2 &= b + bt + bt^2 + \ldots + bt^{n-1}, \end{aligned}$$

be two series in geometric progression. Then

$$C = \begin{cases} \dfrac{ab}{t-r}(t^n - r^n) & \text{if } r \neq t, \\ nabr^{n-1} & \text{if } r = t. \end{cases}$$

Now let

$$S(n,m) = \sum_{r=0}^{n} r^m = 1^m + 2^m + 3^m + \ldots + n^m, \tag{1}$$

be the sum of the mth powers of the first n natural numbers. This series has attracted considerable attention in the last few decades (see, e.g. Mackiw, 2000 and references therein). Many secondary school mathematics texts (see, e.g., Blackey, 1960) devote a section outlining an iterative procedure on how to compute closed formulae for $S(n,m)$, in particular, the cases $m = 1, 2, 3, 4$ are usually covered. However, its self-convolution series

$$\begin{aligned} C &= C(n,m) \qquad (2) \\ &= \sum_{r=1}^{n} r^m[(n+1) - r]^m \\ &= \sum_{r=1}^{n}\sum_{k=0}^{m}(-1)^m(n+1)^{m-r}\binom{m}{k} r^{m+k} \\ &= \sum_{k=0}^{m}(-1)^k(n+1)^{m-r}\binom{m}{k}\sum_{r=1}^{n} r^{m+k} \\ &= \sum_{k=0}^{m}(-1)^k(n+1)^{m-r}\binom{m}{k} S(n, m+k), \end{aligned}$$

has not attracted similar attention. The following results (summarised in Proposition 1 below) can be proved by induction or directly from (2) and Lemma 1. The results in Lemma 1 can be obtained from the iterative procedure mentioned above or from, for example, Comtet (1974, p. 155).

Lemma 1

(a) $S(n,2) \;=\; \dfrac{1}{3}n(n+1)(n+1/2)$

$$
\begin{aligned}
&\text{(b)}\ S(n,3) &=& \frac{1}{4}n^2(n+1)^2\\
&\text{(c)}\ S(n,4) &=& \frac{1}{5}n(n+1)(n+1/2)(n^2+n-1/3)\\
&\text{(d)}\ S(n,5) &=& \frac{1}{6}n^2(n+1)^2(n^2+n-1/2)\\
&\text{(e)}\ S(n,6) &=& \frac{1}{7}n(n+1)(n+1/2)(n^4+2n^3-n+1/3)\\
&\text{(f)}\ S(n,7) &=& \frac{1}{8}n^2(n+1)^2(n^4+2n^3-n^2/3-4n/3+2/3)\\
&\text{(g)}\ S(n,8) &=& \frac{1}{9}n(n+1)(n+1/2)(n^6+3n^5+n^4-3n^3-n^2/5+9n/5-3/5)
\end{aligned}
$$

Proposition 1

Let $S(n,m)$ be as defined in (1) and let $C(n,m)$ be the self-convolution series of $S(n,m)$. Then

$$
\begin{aligned}
&\text{(a)}\ C(n,1) &=& \binom{n+2}{3}\\
&\text{(b)}\ C(n,2) &=& \binom{n+2}{3}\left[\frac{n(n+2)+2}{5}\right]\\
&\text{(c)}\ C(n,3) &=& \binom{n+2}{3}\left[\frac{3n(n+2)(n^2+2n+3)+16}{70}\right]\\
&\text{(d)}\ C(n,4) &=& \binom{n+2}{3}\left[\frac{n(n+2)(n^4+4n^3+8n^2+8n+6)+24}{105}\right]\\
&\text{(e)}\ C(n,5) &=& \binom{n+2}{3}\left[\frac{n^8+8n^7+29n^6+62n^5+86n^4+80n^3+28n^2-24n+192}{462}\right]
\end{aligned}
$$

Remark

The sequences $\{C(n,1)\}$ and $\{C(n,2)\}$ have been recorded as A000292 and A033455, respectively, in Sloane (n.d.). However, $\{C(n,3)\}$, $\{C(n,4)\}$ and $\{C(n,5)\}$ are new. For some selected values of these sequences see the table below.

n	1	2	3	4	5	6	7	8	9
$C(n,1)$	1	4	10	20	35	56	84	120	165
$C(n,2)$	1	8	34	104	259	560	1092	1968	3333
$C(n,3)$	1	16	118	560	2003	5888	14 988	34 176	71 445
$C(n,4)$	1	32	418	3104	16 003	64 064	213 060	614 976	1 587 333
$C(n,5)$	1	64	1510	17 600	130 835	713 216	3 098 604	11 320 320	36 074 325

Exponential convolution

Let $S_1 = \sum_{i=1}^{n} a_1$ and $S_2 = \sum_{i=1}^{n} b_i$. Then the *exponential convolution* of S_1 and S_2 is defined as

$$E \quad = \quad E(S_1, S_2)$$

$$
\begin{aligned}
&= \sum_{i=1}^{n} a_i^{b_{n+1-i}} \\
&= a_1^{b_n} + a_2^{b_{n-1}} + a_3^{b_{n-2}} + \ldots + a_n^{b_1}.
\end{aligned}
$$

Here, even in the special case where

$$S_1 = S_2 = 1 + 2 + 3 + \ldots + n,$$

and hence

$$E = 1^n + 2^{n-1} + 3^{n-2} + \ldots + (n-1)^2 + n^1. \tag{3}$$

It does not appear to be easy to obtain a formula for (3). It would be nice to find one since it leads to other kinds of series like the Fibonacci series, etc. However, if

$$S_1 = \mathrm{e} + \mathrm{e}^2 + \mathrm{e}^3 + \ldots + \mathrm{e}^n,$$

and

$$S_2 = \ln \sqrt[n]{1} + \ln \sqrt[n-1]{2} + \ln \sqrt[n-2]{3} + \ldots + \ln n,$$

then

$$
\begin{aligned}
E &= E(S_1, S_2) \\
&= \sum_{i=1}^{n} (\mathrm{e}^i)^{\ln(n+1-i)^{1/i}} \\
&= \sum_{i=1}^{n} \mathrm{e}^{\ln(n+1-i)} \\
&= \sum_{i=1}^{n} (n+1-i) \\
&= n + (n-1) + (n-2) + \ldots + 2 + 1 \\
&= \frac{n(n+1)}{2}.
\end{aligned}
$$

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Algorithmically generated mathematics course materials

B. Benhammouda

Planning and Training Department, Curriculum and Examinations Section, Technical Studies Institute, Abu Dhabi, United Arab Emirates

Abstract

In this paper, we discuss the teaching of mathematics using algorithmically generated course materials. Using Scientific Workplace, teaching materials such as worked examples, quizzes, examinations, homework assignments, or drills can be easily created by algorithmic instructions. For example, a series of examinations including figures and graphs can be generated from a single examination template. These examinations can be worked and marked online or taken in traditional pencil-and-paper form.

Introduction

Scientific Workplace is a powerful tool that can be effectively exploited in the teaching an learning process. In this paper, we discuss the use of this software as an instructional tool for enhancing the teaching and learning of mathematics. The software can be used as an aid in concepts, skill developments, and problem solving. It can also be used to generate examples, quizzes, examinations, homework assignments, as well as their solutions, quickly. The teaching material produced by this software can be used in classrooms, online, or during office hours. The software can help improving student learning in many topics such as the calculus, linear algebra, numerical and symbolic computations, differential equations, statistics and probability.

Scientific Workplace has three main components: a word processor, a computation engine (based on Maple), and an Exam Builder. These components together form an excellent environment for working with mathematics. One feature of Scientific Workplace is that mathematics can be experienced using natural mathematical notation. One can do mathematics and edit text in the same document without having to master a complex syntax such as Maple or LaTeX. The software also offers an excellent graphical visualisation which can help to illustrate many abstract mathematical concepts. With Scientific Workplace, graphs are easily created, animated, and manipulated interactively to obtain any desired shape, view, or perspective. They can also be automatically generated using algorithms.

An interactive lesson

Graphical visualisation plays an important role in enhancing the teaching of many mathematical concepts. Using graphical visualisation, one can illustrate convergence, continuity, and other concepts (Wei-Chi, 1995).

Example 2.1 (Convergence of sequences)
In Figure 1, we use animation to illustrate the convergence of the sequence $u_n = \left(1+\frac{1}{n}\right)^n$. As n increases, the small circle representing the value of u_n approaches the dotted line of equation $y = 2.7$.

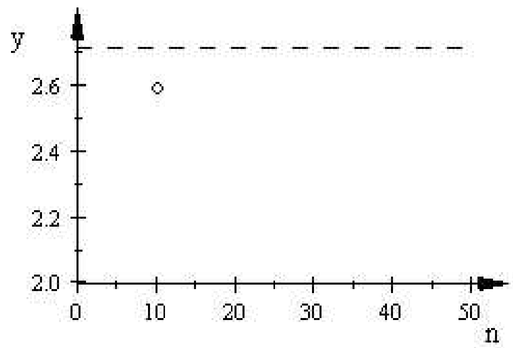

Figure 1: Convergence of the sequence u_n.

Scientific Workplace can also perform symbolic and numerical computations interactively. The following examples show how these computations are performed interactively.

Example 2.2 (Limits)
The computation of limits can be done in one step using the command `Evaluate`.

$$\lim_{x\to -1} \frac{x^3-3x^2+2}{x^4-x^3-x^2+1} = -1.$$

We can also show all steps in the solution using the `factor`, `simplify` and `Evaluate` commands successively.

$$\begin{aligned}
\lim_{x\to -1} \frac{x^3-3x^2+2}{x^4-x^3-x^2+1} &= \lim_{x\to -1} \frac{(x-1)\left(-2x+x^2-2\right)}{(x-1)\left(-x+x^3-1\right)} \\
&= \lim_{x\to -1} \frac{-2x+x^2-2}{-x+x^3-1} \\
&= -1.
\end{aligned}$$

Example 2.3 (Differentiation)
The command `Evaluate` can also be used to perform differentiation.

$$\frac{\partial^3}{\partial x^2 \partial y}\left(x^3 y\right) = 6x.$$

We can also define a piecewise function using the command `Definition + New Definition`.

$$f(x) = \begin{cases} x & \text{if} \quad x < 0 \\ 3x^2 & \text{if} \quad x \geq 0. \end{cases}$$

The command `Evaluate` can be then used to differentiate $f(x)$.

$$\frac{d}{dx} f(x) = \begin{cases} 1 & \text{if} \quad x < 0 \\ 6x & \text{if} \quad x > 0. \end{cases}$$

Example 2.4 (Solution of algebraic equations)
One can use both exact and numerical methods to solve algebraic equations. Here we will consider only the numerical method. To solve the equation $x^3 - 3x^2 + x + 1 = 0$ numerically on $x \in [-1, 3]$, we use the command `Solve+Numeric`.

$$x^3 - 3x^2 + x + 1 = 0, \qquad x \in [-1, 3] \,.$$

The solution is:$\{[x = 1.0], [x = 2.4142], [x = -0.41421]\}$.

Example 2.5 (Matrix algebra)
We can also perform matrix decompositions like the singular value decomposition (SVD) $A = UDV^T$ with U and V real orthogonal matrices, respectively, and D a diagonal matrix with the singular values of A as the first rank(A) diagonal entries. To perform the SVD, we use the command `Matrices+SVD`.

$$\begin{bmatrix} 1 & 2 & 0 \\ -1 & 1 & 1 \\ -1 & -1 & 1 \end{bmatrix} = \begin{bmatrix} 0.81732 & -0.21070 & 0.53628 \\ 5.8459 \times 10^{-2} & -0.89562 & -0.44097 \\ -0.57322 & -0.39176 & 0.71969 \end{bmatrix}$$
$$\times \begin{bmatrix} 2.6787 & 0 & 0 \\ 0 & 1.9164 & 0 \\ 0 & 0 & 0.38959 \end{bmatrix} \times \begin{bmatrix} 0.49728 & 0.84604 & -0.19217 \\ 0.56182 & -0.4828 & -0.67176 \\ 0.66112 & -0.22609 & 0.71541 \end{bmatrix}.$$

Automated examination generation

The Exam Builder of Scientific Workplace is a very useful tool for automatic generation of examinations, quizzes, homework assignments, tutorials and drills. These materials can be easily created by algorithmic instructions. Using the Exam Builder, we can generate a series of examinations and answers, each containing a variant of the questions from the same examination template. The examinations can be randomised by random generation of parameters such as coefficients, functions, intervals, or by selecting different questions from the examination template. In this manner, we can create several different versions from the same examination template. The examinations can be worked and automatically marked online or taken in traditional pencil-and-paper form.

With Exam Builder one can also generate drills and revision sheets. Each student can practise a given skill at length by opening the same file repeatedly, obtaining a slightly different set of questions each time. The drills can include a summary of the lesson and worked examples. The following examples show how instructions can be used to generate randomised examination questions.

Example 3.1 (Solution of equations involving radicals)

> Comment
> Solution of equations involving radicals.
> Setup
> $a := \text{rand}(-10, 5)$
> $p := \text{rand}(-5, 10)$
> $q := \text{rand}(-5, 10)$
> Condition: $(pq \neq 0) \wedge (p \geq a) \wedge (q \geq a)$
> Statement
> Solve the equation $x - a = \sqrt{(p+q-2a)x + a^2 - pq}$.

With these instructions, Exam Builder generates three numbers $a \in [-10, 5]$, $p \in [-5, 10]$ and $q \in [-5, 10]$ randomly then constructs equations of the form $x - a = \sqrt{mx + b}$ with solutions $x = p$ and $x = q$. For example, when the values $a = 2, p = 3$ and $q = 4$ are randomly selected, Exam Builder will generate the following question

1. Solve the equation $x - 2 = \sqrt{3x - 8}$.

Exam Builder will also generate the solution if the following two lines are added to the above instructions

> Answer
> The solutions are $x = p$ and $x = q$.

For the equation $x - 2 = \sqrt{3x - 8}$, the answer generated is

Answer
The solutions are $x = 3$ and $x = 4$.

With Exam Builder, we can also give all solution steps in the answer

Answer

$$
\begin{aligned}
x - a = \sqrt{(p+q-2a)x + a^2 - pq} \quad &\Longleftrightarrow \quad \begin{cases} (x-a)^2 = (p+q-2a)x + a^2 - pq \\ \; x \geq a \end{cases} \\
&\Longleftrightarrow \quad x^2 - (p+q)x + pq = 0\ ,\ x \geq a \\
&\Longleftrightarrow \quad (x-p)(x-q) = 0,\ x \geq a \\
&\Longleftrightarrow \quad x = p \text{ or } x = q.
\end{aligned}
$$

With these algorithmic steps, the solution steps for $x - 2 = \sqrt{3x - 8}$ are generated in the following manner

$$
\begin{aligned}
x - 2 = \sqrt{3x - 8} \quad &\Longleftrightarrow \quad \begin{cases} (x-2)^2 = 3x - 8 \\ \; x \geq 2 \end{cases} \\
&\Longleftrightarrow \quad x^2 - 7x + 12 = 0\ ,\ x \geq 2 \\
&\Longleftrightarrow \quad (x-3)(x-4) = 0,\ x \geq 2 \\
&\Longleftrightarrow \quad x = 3 \text{ or } x = 4.
\end{aligned}
$$

Example 3.2 (Factorising polynomials)

> Comment
> Factorising polynomials.
> Setup
> $p := \text{rand}(-20, 20)$
> $q := \text{rand}(-20, 20)$
> Condition: $(pq \neq 0)$
> Statement
> Factorise the polynomial $x^2 - (p+q)x + pq$.

With these instructions, Exam Builder generates two numbers $p, q \in [-20, 20]$ randomly then constructs polynomials of the form $x^2 - (p+q)x + pq$ with solutions $x = p$ and $x = q$. For example, when the values $p = -3$ and $q = 2$ are randomly selected, Exam Builder will generate the following question

1. Factorise the polynomial $x^2 + x - 6$.

Exam Builder will also generate the answer if the following two lines are added to the above instructions

> Answer
> The factorised form of $x^2 - (p+q)x + pq$ is $(x-p)(x-q)$.

The answer to question one is

Answer
The factorised form of $x^2 + x - 6$ is $(x+3)(x-2)$.

As in the previous example, we can also show all solution steps in the answer as follows

Answer

$$\begin{aligned} x^2 - (p+q)x + pq &= x^2 - px - qx + pq \\ &= x(x-p) - q(x-p) \\ &= (x-p)(x-q). \end{aligned}$$

With these algorithmic factorisation steps, the steps for factorising $x^2 + x - 6$ are generated in the following manner

$$\begin{aligned} x^2 + x - 6 &= x^2 + 3x - 2x - 6 \\ &= x(x+3) - 2(x+3) \\ &= (x+3)(x-2). \end{aligned}$$

Example 3.3 (Synthetic division)

> Comment
> Synthetic division.
> Setup
> $a_4 := \text{rand}(-5, 5)$
> $a_3 := \text{rand}(-5, 5)$
> $a_2 := \text{rand}(-5, 5)$
> $a_1 := \text{rand}(-5, 5)$
> $a_0 := \text{rand}(-5, 5)$
> $p := \text{rand}(-5, 5)$
> $c_3 := a_4$
> $b_3 := rc_3$
> $c_2 := a_3 + b_3$
> $b_2 := rc_2$
> $c_1 := a_2 + b_2$
> $b_1 := rc_1$
> $c_0 := a_1 + b_1$
> $b_0 := rc_0$
> $r := a_0 + b_0$
> Condition: $(ra_4 \neq 0)$
> Statement
> By synthetic division, divide $a_4x^4 + a_3x^3 + a_2x^2 + a_1x + a_0$ by $x - p$.

We can also generate all solution steps in the answer by adding the following instructions to the instructions given above

Answer

$$\begin{array}{ccccc|l} a_4 & a_3 & a_2 & a_1 & a_0 & p \\ \hline & \underline{b_3} & \underline{b_2} & \underline{b_1} & \underline{b_0} & \\ c_3 & c_2 & c_1 & c_0 & r & \end{array}$$

From these results one has

$(a_4x^4 + a_3x^3 + a_2x^2 + a_1x + a_0) : (x - p) = c_3x^3 + c_2x^2 + c_1x + c_0$ with remainder r.

For example, for the division of $(x^4 - 6x^3 + 11x^2 - 13x + 6)$ by $(x - 4)$, the above algorithm will generate the following solution steps

Answer

$$\begin{array}{rrrrr|l} 1 & -6 & 11 & -13 & 6 & 4 \\ \hline & \underline{4} & \underline{-8} & \underline{12} & \underline{-4} & \\ 1 & -2 & 3 & -1 & 2 & \end{array}$$

From these results, we have

$(x^4 - 6x^3 + 11x^2 - 13x + 6) : (x - 4) = x^3 - 2x^2 + 3x - 1$ with remainder 2.

Reference

WEI-CHI, Y. (1995). *Examples from calculus with Scientific Workplace* [online]. Available from: http://archives.math.utk.edu/ICTCM/EP-8/C56

A finite difference solution to a solute transport problem using a spreadsheet program

A. Kharab

Department of Mathematical Science, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

Abstract

Solutions to a transient solute transport problem can be performed readily using spreadsheet software. This paper presents a single 1-2-3 macro program that finds the numerical solutions of two model problems describing transient and steady-state solute transport through a large soil column. The two models are governed by the convection-dispersion equation but are subject to different initial and boundary conditions. A finite-difference method is used in the numerical scheme and examples showing how to implement the numerical spreadsheet solution are given.

Introduction

Increased public awareness of significant contamination of groundwater by industrial, municipal, and agricultural chemicals has focused much attention on solute movement. The disposal of chemical wastes, on and in the soil, pose a threat to the quality of soil and ground-water resources. The transport through soil of numerous interacting solutes has been studied theoretically and experimentally for many years (see, e.g., Parker, 1984; van Genuchten and Parker, 1994; Kharab and Guenther, 1994). For unsaturated soil, the transport of these solutes if often described by the one-dimensional convection-dispersion equation (CDE)

$$\frac{\partial(\theta C)}{\partial t} + \frac{\partial(\rho S)}{\partial t} = \frac{\partial}{\partial x}\left(\theta D_e \frac{\partial C}{\partial x} - qC\right). \tag{1}$$

Here C is the solution concentration; θ is the soil moisture content; ρ is the bulk density; S is the adsorbed concentration; D_e is the dispersion coefficient; q is the liquid flux density; t is time, and x is distance. Under certain conditions, equation (1) may be simplified. This paper demonstrates the relative ease of creating a spreadsheet program to find the numerical solution of (1) for steady-state flow conditions where soil moisture and pore-water velocity are constant. The spreadsheet method presented here offers several advantages including efficient data input, and the ability to analyse data using multiple choices of charts available in the spreadsheet. In addition, it allows users

with little or no experience with Lotus 1-2-3 to run the program once installed and to experiment with the model problem with various sets of data.

There has been much interest recently in the use of spreadsheets in all fields. Kharab (1995) used a spreadsheet program for the numerical solution of a two-dimensional heat conduction problem. Olsthoorn (1985) describes the use of spreadsheets in modelling various ground water flow problems using finite-difference methods while O'Neal (1987) describes the use of a spreadsheet for the numerical solution of a one-dimensional transient heat conduction problem using an implicit and explicit method. In engineering, they have been used for analysing logical networks (Rao, 1984) and solving differential equations (Hagler, 1987). Although spreadsheets have been used for many engineering and science applications, exploitation of the spreadsheet to this depth, as done in this study, is rare.

Among the advantages of using a spreadsheet are the on-screen numerical and visual feedback, fast calculations and the built-in graphics capabilities that permit the display of results on the screen with little effort. They also provide a clear and direct means of entering data and formula. These powerful facilities will enable students to explore and experiment with many physical models that have a visual aspect to them, without having to get involved in lengthy calculations.

Model problem

Since most of the experimental studies on miscible displacement have been performed under laboratory conditions with temporary and spatial constant flow velocity and water content, we consider an experiment where water is flowing uniformly at a steady state through a large homogeneous soil column of length L that is at a constant water content. Under such conditions equation (1) reduces to the classical CDE

$$\frac{\partial C}{\partial t} = D\,\frac{\partial^2 C}{\partial x^2} - v\,\frac{\partial C}{\partial x}, \tag{2}$$

where D is a field-scale dispersion coefficient and v the averaged pore-water velocity, both assumed to be constant. We will consider two free-phase models.

Model I

At $t = 0$, we instantaneously switch the water inlet valve of the soil column from its initial tracer-free source to a chemical solution at a concentration C_0, which continues to flow at the same flux rate through the column. The chloride concentration will be monitored at the outflow end $x = L$ of the column, from $t = 0$ onward.

Following van Genuchten and Parker (1994), the corresponding initial and boundary conditions are

$$\begin{aligned} C(x,0) &= 0, & 0 < x < L, \qquad (3)\\ -DC_x + vC &= vC_0, & x = 0,\ t > 0, \qquad (4)\\ C_x &= 0, & x = L,\ t > 0. \qquad (5) \end{aligned}$$

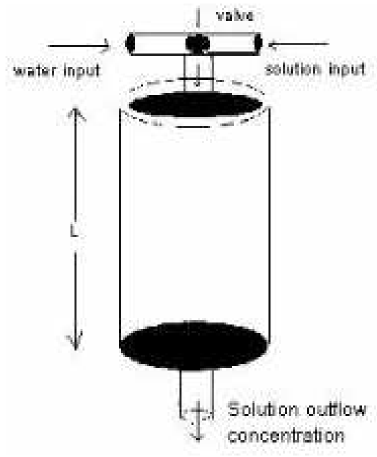

Figure 1: Experimental setup.

Model II

In this model we assume that an initial distribution of chemical $C_0 f(x)$ exists at $t = 0$. This can be obtained in the experiment by bringing into contact with the end, $x = 0$, of a large soil column saturated with water, a reservoir containing a chemical of known concentration. Allow the reservoir to be in place for a certain time and then remove it so that the chemical distribution in the soil column becomes $t = 0$

$$C(x, 0) = C_0 f(x), \qquad 0 < x < L. \tag{6}$$

The corresponding boundary conditions are (see van Genuchten and Parker, 1994)

$$-DC_x + vC = 0, \quad x = 0,\ t > 0, \tag{7}$$
$$C_x = 0, \quad x = L,\ t > 0. \tag{8}$$

Equation (3) indicates that the soil column is initially free of any chemical. In contrast, equation (6) indicates that the soil column contains an initial distribution of a chemical. Equations (4) and (7) are equivalent to a statement of conservation of mass across the inlet, and equations (5) and (8) come from the assumption that the solute concentration should be continuous across the lower boundary $x = L$.

Difference equation

An explicit finite difference approximation of the governing equation (2) may be expressed at the $t_n + k$ time level using a forward difference on the time step and a central difference for the convection term. The resulting finite difference equation is (for further details see Mitchell and Griffiths, 1980).

$$C_j^{n+1} = C_j^n + D\lambda\left[C_{j-1}^n - 2C_j^n + C_{j+1}^n\right] - \frac{k\,v}{2h}\left[C_{j+1}^n - C_{j-1}^n\right], \tag{9}$$

$$j = 1,2,...,M-1, \quad n = 0,1,...$$

where the subscripts j and n denote the discretised space and time domain and $C_j^k = C(x_j,t_n) = C(jh,nk)$; $\lambda = k/h^2$.

Applying the central finite difference to the top and bottom boundary conditions, for each model one obtains:

Model I

$$C_{-1}^n = \frac{2hv}{D}\,(C_0 - C_0^n) + C_1^n, \tag{10}$$

$$C_{M+1}^n = C_{M-1}^n. \tag{11}$$

Setting $j = 0$ in (6) and replacing C_{-1}^n from (7) we get

$$C_0^{n+1} = C_0^n\left(1 - \frac{k\,v^2}{D}\right) + 2D\lambda\left[C_1^n - C_0^n(1+\frac{hv}{D}) + \frac{hv}{D}\right] + \frac{k\,v^2C_0}{D}, \tag{12}$$

and similarly by setting $j = N$ in (6) and replacing C_{-1}^n from (8) we get for each model:

$$C_M^{n+1} = C_M^n + 2D\lambda\left[C_{M-1}^n - C_M^n\right]. \tag{13}$$

Model II

$$C_{-1}^n = C_1^n - \frac{2hv}{D}C_0^n, \tag{14}$$

$$C_{M+1}^n = C_{M-1}^n. \tag{15}$$

Setting $j = 0$ in (6) and replacing C_{-1}^n from (11) we obtain

$$C_0^{n+1} = C_0^n\left(1 - \frac{k\,v^2}{D}\right) + 2D\lambda\left[C_1^n - C_0^n(1+\frac{hv}{D})\right], \tag{16}$$

and similarly by setting $j = N$ in (6) and replacing C_{-1}^n from (12) we obtain

$$C_M^{n+1} = C_M^n + 2D\lambda\left[C_{M-1}^n - C_M^n\right]. \tag{17}$$

The initial conditions $C(x,0) = 0$ and $C(x,0) = C_0 f(x)$ become

$$C_j^0 = 0, \text{ and } C_j^0 = C_0 f(x_j), \quad j = 0,1,...,M. \tag{18}$$

respectively. It can be shown (Mitchell and Griffiths, 1980) that the difference scheme simulated is $O(k + h^2)$.

We used an explicit scheme for the numerical solution because it is very well suited for a spreadsheet and it involves a simple algorithm. The only restriction is that $D\lambda \leq 1/2$ to ensure the stability of the numerical process, this will require small time steps. However, with the increase in speed and memory size of powerful personal computers, this condition should not cause any problem. In addition to the condition on the mesh ratio $D\lambda$, it should be observed that the mesh Peclet number should satisfy the condition

$$P_e = \frac{vh}{D} \leq 2$$

in order to avoid oscillations in the solution.

Spreadsheet program and description

The text of the macro program that finds the numerical solution of both models I and II is shown in Figure 2. It should be stored within a Lotus 1-2-3 worksheet. In writing the 1-2-3 macro, we used Columns ID, IE and IF away from the range of output. When entering the macro into a 1-2-3 worksheet, one should make sure that it is written exactly as shown. Here, one is required to start at cell ID1 and finish at cell IF50.

Set Panel off.	{HOME}{PANELOFF}		
Reset all range names	/rnr~/rnc\A~ID1~		
Erase range of output.	{BLANK A3..HZ100}~		
Set screen display off.	{WINDOWSOFF}~		
	/rncDX~IA1~/rncLD~IA2~		
Define the variables:	/rncX~IA3~/rncJ~IA4~		
DX, LD, X, J,	/rncN~IA5~/rncK~IA6~		
N, K, FLAG, T.	/rncFLAG~IA7~/rncT~B4~		
M, L, DT, F(X),	/rncM~A2~/rncL~B2~		
TX, V, D.	/rncDT~C2~/rncF(X)~D2~		
	/rncTX~E2~/rncV~F2~/rncD~G2~		
	{GOTO}A4~^x \ t~		
Create range "C".	{GOTO}B5~/rncC~{R}{D M}~		
Set t=0, x=0.	{LET T,0}~{LET X,0}~		
Computes DX, M.	{LET DX,L/M}~{LET N,TX/DT}~		
Computes LD.	{LET LD,DT/(DX^2)}~		
	{GOTO}A5~0~{D}+A5+$DX~/c~.{D M-1}~		
Check on the method	{IF H2=1}{LET FLAG,1}{BRANCH ID20}~		
to use I or II.	{LET FLAG,0}~		
Set screen display on.	{WINDOWSON}~		
	{GOTO}C~		
FOR Loop 1	{FOR J,0,M,1,IE26}~		
FOR Loop 2	{FOR K,0,N,1,IE31}~		
	{QUIT}~		
		+f(x)~/rv~~	
Compute the initial		{DOWN}	
concentration.		{LET X,X+DX}~	
		{RETURN}~	
		{GOTO}C~{R}~	
FOR Loop 3		{FOR J,0,M,1,IF42}~	
		{IF K<1}{BRANCH IE38}~	
		{IF @MOD(K,J2)=0}{BRANCH IE38}~	
Control the output		{GOTO}C~{ESC}{R}{LET T,K*DT}~	
frequency of Cj.		/m.{D M}~{L}~{L}/rncC~{ESC}.{D M}~	
		{BRANCH IE40}~	
		{LET T,K*DT}~/rncT~{R}~	
		/rncC~{ESC}{R}.{D M}~	
		{RETURN}~	
			{LET IM1,@INDEX(C,0,1)-@INDEX(C,0,0)*(1+DX*v/D)+FLAG*v*DX/D}~
			{LET IM2,@INDEX(C,0,J-1)-2*@INDEX(C,0,J)+@INDEX(C,0,J+1)}~
			{LET IM3,@INDEX(C,0,M-1)-@INDEX(C,0,M)}~
Computes C at B.C., J=0			{IF J=0}{LET IM4,@INDEX(C,0,0)*(1-DT*v^2/D)+2*LD*D*IM1+FLAG*v^2*DT/D}~{BRANCH IF48}
Computes C at B.C., J=M			{IF J=M}{LET IM4,@INDEX(C,0,M)+2*LD*D*IM3}~{BRANCH IF48}
Computes Cj from Eq. (6)			{LET IM4,@INDEX(C,0,J)+LD*D*IM2-DT*v/(2*DX)*(@INDEX(C,0,J+1)-@INDEX(C,0,J-1))}~
			+IM4~/rv~~
			{DOWN}
			{RETURN}~

Figure 2: Listing of the 1-2-3 macro.

The computational molecule of the main difference equation (6) is shown in Figure 3. There are three FOR loops in the program. Loop 1, contained in cell ID22, is used to compute the initial concentration. Loop 2 and 3 contained in cells ID23 and IE32 respectively, compute the concentration at different time levels. The time level t_n is set by Loop 2 and the space level x_j is set by Loop 3.

The way the computational molecule shown in Figure 3 operates in the program is as follows. Since the concentration at each time-step is obtained in terms of the concentrations in the previous time-step, a range named ‘C’, containing the values of C_j^{n-1}, is defined at each time level $t = t_n$ to compute the values of C_j^n from

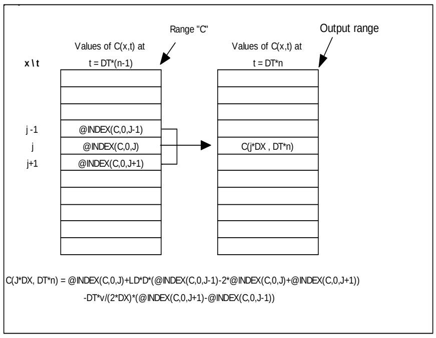

Figure 3: Computational molecule of equation (6).

equations (6), (9) and (10) for model I and (6), (13) and (14) for model II. The 1-2-3 function @INDEX is used to compute C_j^n. This function plays the same role as arrays do in FORTRAN. It gives the value contained in any cell within a defined range. For example, @INDEX(C,0,3) is equal to the value contained in the cell located in the first column and the fourth row of the range 'C'. The command that computes the values of C at $j = 1, ..., M$ is contained in cell IF47. The ones which compute the values of C at the boundaries $x = 0$ and $x = L$ are contained in cell IF45 and IF46 respectively.

At the end of the each time step t_n, the range 'C' is moved one column to the right (see Figure 4) in order to compute the values of the concentration for the next time level t_{n+1}. The program terminates when $t_n = TX$.

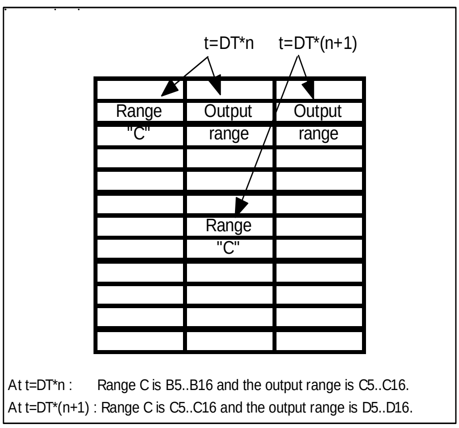

Figure 4: Position of the range 'C' at different time levels.

A	A	B	C	D	E	F	G	H
1	M	L	DT	$f(x)$	TX	v	D	Model
2	10	30	0.01	0	10	3.5	15.7	1

Figure 5: Input data.

Parameters	Model I	Model II	units
D	31.5	0.8	cm^2/day
v	3.1	3.2	cm /day
L	30	10	cm
TX	40	7	days
$f(x)$	0	0.5	

Table 1: Model parameters used.

How to enter the input data

The data needed to run the 1-2-3 macro is M, L, DT, $f(x)$, TX, v, D and Model contained in cells A2, B2, C2, D2, E2, F2, G2 and H2 respectively, shown in Figure 5. To enter any one of these data, just move the cursor to the appropriate cell and type its value. For example, if $f(x) = 2x$ and $D = 15.7$, move the cursor to cell D2 and type the formula: 2*x to enter $f(x)$ and then move the cursor to cell G2 and type 15.7 to enter D. For the choice of the model problem, enter in cell H2 1 for model I, or 2 for model II. In order to control the printings of the concentration at each time, enter in cell J2 the number of time-steps between successive printings of concentrations.

How to run the 1-2-3 macro

Once the 1-2-3 macro is entered in its entirety into a 1-2-3 worksheet, name it, for example 'Alt A' by moving the cursor to cell ID1 and using the command '/rnc'. Enter the input data as shown in Figure 5. Now invoke the 1-2-3 macro by pressing the Alt-A key. The program will terminate when t reaches the maximum value allowed given by TX. The calculations can be repeated in their entirety for any set of input data by simply entering the new data and then running the macro again.

Numerical results

The spreadsheet program will now be used to find the relative concentration and the breakthrough curves in both models I and II. The following parameters were chosen in obtaining the solutions shown in Figures 6 to 11.

Figures 6 to 11 show the output of the 1-2-3 macro program for model I and II respectively using the input data given in Table 1 calculated with $k = 0.01$ and $h = 0.5$ (I) and $h = 3.0$ (II). Note that the numbers in cell I2 correspond to the number of time-steps between successive printings of concentrations. The breakthrough curves for model I and II are shown in Figures 6 and 8 respectively, and the plots of the relative concentration at different time levels are given in Figure 7 for model I and in Figure 9 for model II.

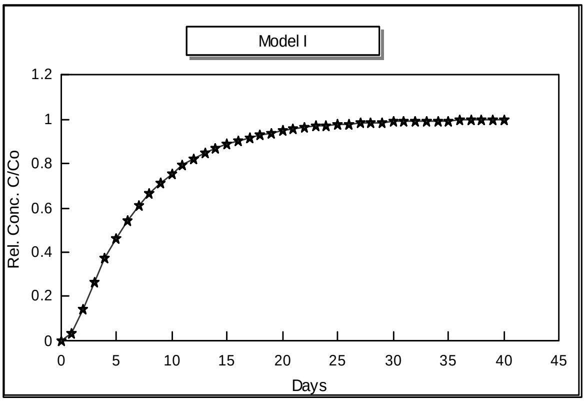

Figure 6: Breakthrough curve under transient steady-state conditions with $k = 0.01$ and $h = 0.5$ for model I.

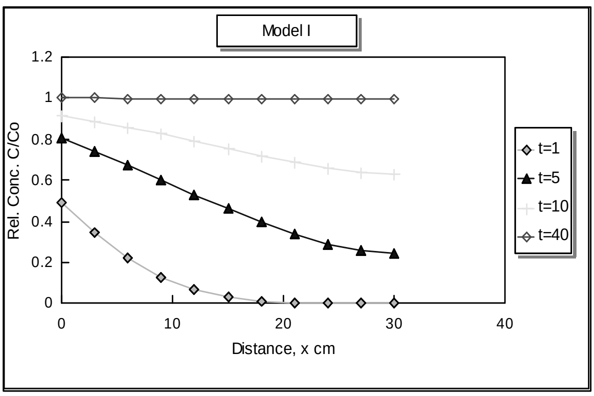

Figure 7: Relative concentration versus distance along the column at different time levels calculated with $k = 0.01$ and $h = 3$ for model I.

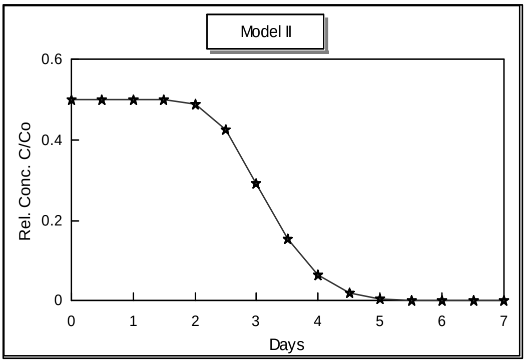

Figure 8: Breakthrough curve under transient steady-state conditions with $k = 0.01$ and $h = 0.5$ for model II.

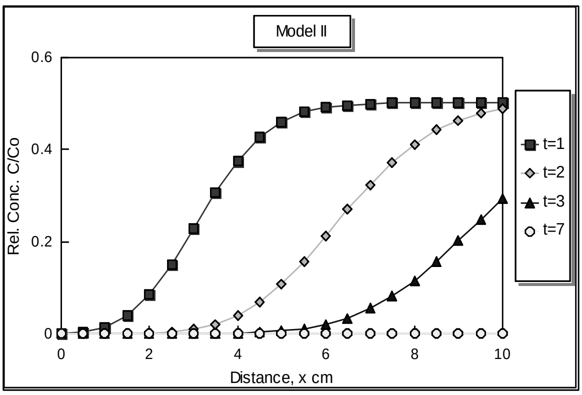

Figure 9: Relative concentration versus distance along the column at different time levels calculated with $k = 0.01$ and $h = 0.5$ for model II.

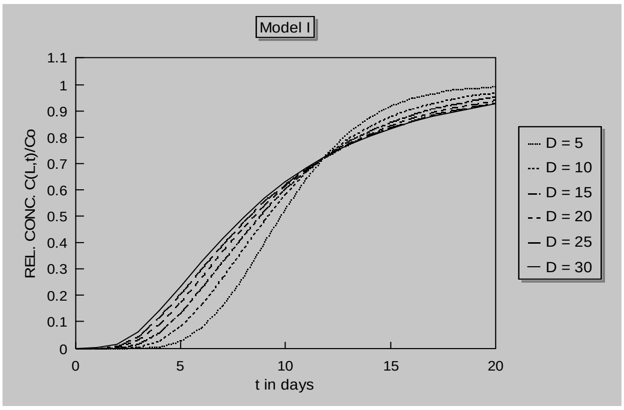

Figure 10: Breakthrough curves for $k = 0.01$, $h = 3$ and $v = 3.1$ for model I.

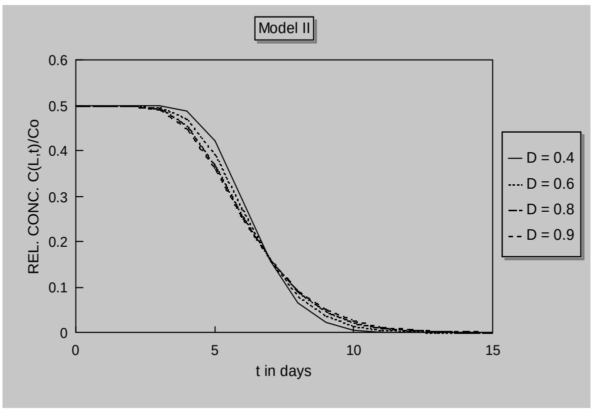

Figure 11: Breakthrough curves for $k = 0.01$, $h = 0.5$ and $v = 1.6$ for model II.

Figures 10 and 11 show the relative outflow concentration versus time for different values of D calculated with $k = 0.01$, $h = 3$ (I), $h = 0.5$ (II), $v = 3.1$ (I), and $v = 1.6$ (II). As seen in these figures, the effect of dispersion on the breakthrough curve is to cause some early and late arrival of solute with respect to the breakthrough time.

Concluding remarks

Two spreadsheet models for a general solute transport problem in a homogeneous soil column have been presented. The experiments show that spreadsheets provide an ideal environment for obtaining solutions of solute problems. The process is very user-friendly and could be applied by students in science and engineering to the modelling of transient and steady-state solute transport problems. It is characterised by easy data manipulation and on-screen numerical and visual feedback. The spreadsheet method is flexible and can be extended to solve more advanced problems which might be of interest in student research projects.

Acknowledgement

The author wishes to acknowledge the support of King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Appendix

List of principal variables used in the spreadsheet program shown in Figure 2.

$DT = k$
$DX = h$
$X = x$
$T = t =$ time.
$LD = \lambda$
$J, K, M, N =$ indices.
$C =$ name of the range containing the values of C at the previous time-step.
$D =$ Dispersion coefficient.
$V =$ pore-size velocity.
$F(x) = f(x) =$ initial temperature distribution.
$L =$ length of the column.
$TX =$ largest value of t to be considered.

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Exploring topics in mathematics using computer software

Abdelkader Dendane

University General Requirement Unit, United Arab Emirates University, Al Ain, United Arab Emirates

Abstract

Learning and understanding mathematics involves processes in which students connect with and build upon existing knowledge. Exploring topics and concepts in mathematics is an activity in which students engage in connections with past experience and high level thinking. The use of computer software makes it easy to create an environment for the exploration and (re-) discovery of mathematical concepts. However, students may not have the necessary skills for exploring and searching, and therefore need to be guided during these activities with the teacher playing the role of facilitator. The design of these activities is very important; students 'construct' knowledge in steps with what they already know. This paper discusses ideas for designing classroom activities in which students, in groups of two to three, use DERIVE to explore topics in mathematics by changing parameters in a given mathematical object.

Introduction

One of the major difficulties in learning mathematics is that concepts are closely linked. One encounters problems in calculus if one does not have a deep understanding of algebraic concepts. In general, students with deep conceptual understanding of mathematics are less likely to have problems in understanding and learning new topics. They also enjoy their mathematics classes and are usually intrinsically motivated.

Learning and understanding mathematics involves processes in which students connect to and build on knowledge already acquired (National Council of Teachers of Mathematics, 2000). Making connections between prior knowledge and new information to construct new knowledge is an indication of learning with deep understanding (Mackie, 2002). We, therefore, need to develop easy-to-use classroom activities in which prior knowledge is activated.

Exploring topics in mathematics for the purpose of discovering, understanding, and acquiring unknown information, involves using and connecting prior knowledge to understand and construct new knowledge. The process of exploring topics in mathematics is as important as the end product. Students acquire lifelong skills such as self-learning, high-level thinking, and co-operative learning.

Exploration and connection using computer software

Computer software such as computer algebra systems, Excel, and Java applets can be used to present past knowledge in an easy to understand format, such as graphs. They are efficient when dealing with large amounts of information. As an example, let us consider the following question.

> A plane curve is defined by the parametric equations $x = 2\sin(t - \pi/3)$, $y = \sin(t+7\pi/6)$. Find the Cartesian equation for the curve by eliminating the parameter t.

Although an analytical answer to this question is not obvious to the average student, using software gives a graphical solution with little effort (see Figure 1). More importantly, it could give clues on how to connect a question to existing knowledge and help to generate an analytical answer.

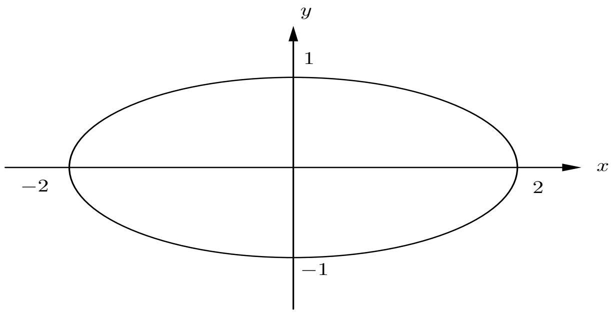


Figure 1: Graphical solution to the above question.

Most students are competent at visual interpretations and welcome any illustrations of concepts. Therefore, opportunities should be given to students to explore topics in mathematics graphically.

Graphical, numerical, and symbolic representations of the same mathematical object allow students to explore relationships that emerge as parameters included in this object are changed. The use of computer software provides an ideal environment for students to develop multiple representations and deep understanding of mathematical ideas (Pierce and Stacey, 2001). For example, a quadratic function might take any one of the representations shown in Table 1.

The use of computer software makes it easy to create a constructivist learning environment. As seen in the above example, a graphical representation of a mathematical object might be useful in making connections to prior knowledge. Also, students connect between the different representations and construct their own understanding of mathematical concepts (Murphy, 1999). Computer software eliminates a lot of the tedious work, such as graphing, and leaves more time for connection and high level thinking (Lindsay, 2006).

Moreover, computer-based learning is well suited to a student-centred exploratory approach where students work in groups and teachers play the role of a facilitator who

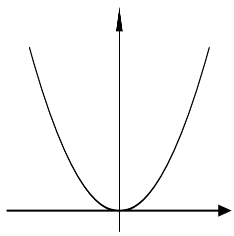
<table>
<tr><th>Symbolic</th><th>Graphical</th><th>Numerical</th></tr>
<tr><td>$f(x) = x^2$</td><td></td><td><table><tr><th>x</th><th>$f(x)$</th></tr><tr><td>-2</td><td>4</td></tr><tr><td>-1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td></tr><tr><td>2</td><td>4</td></tr></table></td></tr>
</table>

Table 1: Three possible representations of the same mathematical object

encourages students to construct new knowledge. Group work is greatly enhanced by the use of software. Each member has a role which is important to the group. In using software to explore topics in groups, students understand the advantages of working co-operatively and student motivation is enhanced (Johnson, Johnson and Smith, 1991). It also gives the opportunity to work in conditions similar to those in any future work place. Each member of the group must understand that his or her efforts benefit the whole group (Johnson, Johnson and Holubec, 1994).

As an example, I now describe activities designed to guide students in exploring specific topics in mathematics. The worksheet presented in the appendix was used by students of the University General Requirement Unit at United Arab Emirates University (UAEU). At the foundation level, these students do not have the necessary skills to explore topics in mathematics on their own. Initially, they need to be guided in their exploration, hence the step by step approach followed in the worksheet. The worksheet was designed so that students engage in exploring the characteristics of a quadratic function in vertex form, namely $f(x) = a(x - h)^2 + k$.

In order to understand the relationship between algebraic and graphical representations of quadratic functions students experimented with various values for the parameters a, h and k by trying to understand and answer questions in the worksheet. The majority of students, including the less able, used these worksheets without major difficulties and with little help from their teacher.

Later in the semester, students became more confident in using computer software and were required to explore topics and concepts with much less guidance. As an example, they were asked to explore the relationship between functions f and g defined by $f(x) = a^x$ and $g(x) = \log_a x$.

These types of explorations were more demanding on students. Some students managed to finish the work within the allotted time while many others needed more. Initially, these types of explorations gave rise to a lot of confusion and frustration. However, students gradually realised that they needed genuine co-operation within the

group to be able to start exploring the two functions. These explorations needed more effort and time and, therefore, were of great benefit to them. Besides the new information acquired through explorations, students practiced the process of exploring the two functions, working and communicating in a group, high-level thinking, accessing prior knowledge and self-learning. These skills are needed at university and beyond, especially at any future work place.

Students evaluation

Sixty-six students answered questions related to the use of DERIVE in mathematics. In this section, I present the main results of this study.

The use of DERIVE helped students learn and understand mathematics easily (see comments C1, C2 and C3 in the table over page). All the graphing and handling of mathematical expressions was done by the computer. Therefore, more time was left for experimenting, exploring and thinking (comment C2). Students greatly enjoyed using DERIVE to explore new topics in mathematics and were fully engaged in their activities. The idea of exploring to construct knowledge had positive effects on student motivation. On their own, the students made rules and interpreted illustrations to understand mathematical concepts and objects.

Group work and student-to-student interaction were some of the main activities while using DERIVE. They found it natural to work in groups where one student typed and edited, another student sketched graphs on the worksheet and the third organised all activities and communicated findings. Interpretation of the results was done by the group. Although no student mentioned group work in their comments, students enjoyed it and understood its strengths.

Although deep learning was not mentioned in any of the questions put to the students, comments C4 and C5 show that at least they were aware of it and perhaps compared their own different learning styles – active learning using DERIVE, versus passive. One learns a topic deeply if one can fluently explain the concept and the skill behind it. At least some of my students were able to explain to me and other students the concepts they had learnt during class discussions. In examinations, students performed consistently better at graphing questions. This is perhaps due to the fact that most of the topics explored using DERIVE used graphical and symbolic representations and the connections between them.

Comment C3 reveals that the less able students benefited from using DERIVE and, more importantly, were aware of it. The fourth question in the questionnaire perhaps reveals to what extent students felt about using DERIVE to explore topics in mathematics. Almost all confirmed that they would like to use DERIVE or similar computer software to learn mathematical topics in the future (see also comments C7, C8 and C9).

Question 1: Had you used DERIVE or any similar software (to learn mathematics) before you came to the UAEU?	Only four confirmed that they had used DERIVE before they came to university.
Question 2: Did you enjoy using DERIVE in your mathematics lessons this semester?	Sixty students said they enjoyed using derive. C1: 'Yes, because I enjoy things that can help to learn by using computer program'. C2: 'Yes, it helped us to graph functions that might take a long time to do by hand'. C3: 'Yes, it helps me to understand the lesson well. It is also good because it helps weak students understand work by themselves'.
Question 3: Does DERIVE help you learn mathematics better?	Fifty-four students said DERIVE helped them. C4: 'Yes, because I think we try to find the solution by graphing, we learn more and the information is constant in our mind'. C5: 'Yes, it expands our imagination to understand the questions'. C6: 'No, we can use DERIVE in long and very complicated functions but not all of them because it will teach students to be lazy'.
Question 4: Would you like to use DERIVE or any similar software in your mathematics lessons in the future?	Almost all students confirmed that they would like to use DERIVE in the future, however some of them had some reservations. C7: 'Yes, because in engineering we will face a lot of complicated functions to graph'. C8: 'Yes of course, it may help in understanding math better'. C9: 'Yes but not in all things because we must use our hands'.

Conclusion

The main idea is to let students construct their own knowledge and meaning by exploring topics. Computer applications are capable of creating learning environments where students are fully engaged in exploring activities that lead to learning with understanding. Observing my students using applications to explore topics in mathematics, I can

say that they enjoyed classroom activities involving them. They were easily engaged in group work with strong student-to-student interactions and understood the benefits. They spent more time experimenting, exploring, and thinking than manipulating expressions and sketching graphs. Looking at the same concept using different graphical, numerical, and algebraic representations surprised them. It created a curiosity which helped to further expand their knowledge.

The design of the worksheets must take into account students' ability to explore topics on their own. At the start of the semester, worksheets contained all the steps necessary to guide students through their explorations. However, later in the semester as students gained more experience in exploration, the worksheets contained less information in order to give the students opportunities to decide on what direction to follow in order to explore the topic under consideration. It emerged, however, that given less information, students needed more time to finish the assigned task. Some of the learning styles and habits acquired when using computer software will undoubtedly have long-term positive effects. However short-term effects need also to be accurately assessed.

Finally, at the pre-calculus level, it would be very useful if students were trained to explore topics in mathematics using computer applications. This would not only help them to understand pre-calculus topics better, but also train them for future explorations of topics in calculus.

Appendix: Sample worksheet used to explore quadratic functions

Objective: At the end of this activity, students will be able to describe the effects of the parameters a, h and k on the graph of quadratic functions of the form $f(x) = a(x-h)^2 + k$.

1 – Explore the effects of coefficient a

Set coefficients h and k both to zero. Now graph function f for values of the coefficient a equal to positive values: 1, 2, 3 and 4, then negative values -1,-2,-3 and -4.

(a) Sketch the graphs obtained in your notebook. Explain the main difference(s) between graphs with positive and negative a.

(b) The vertex is the point at which the graph of function f changes from increasing to decreasing (or vice versa). Does the position of the vertex change as you change the coefficient a?

2 – Explore the effects of coefficient k

Set coefficient a to 1 and coefficient h to 2. Now graph function f for values of k equal to -3, -2, -1, 0, 1, 2, 3.

(a) Sketch the graphs obtained and explain the main difference(s) between graphs with positive, negative and zero k?

(b) Which of the co-ordinates of the vertex changes and how?

3 – Explore the effects of coefficient h

Set coefficients a and k both equal to 1. Now graph function f for values of h equal to -3, -2, -1, 0, 1, 2, 3.

(a) Sketch the graphs obtained and explain the main difference(s) between graphs with positive, negative and zero h.

(b) Which of the co-ordinates of the vertex changes and how?

4 – Predict the properties and sketch the graphs of quadratic functions
What are the co-ordinates of the vertex of the graph of function f given by $f(x) = -2(x-2)^2 + 2$.

(a) Determine the interval of increase and the interval of decrease for the function f.

(b) Sketch the graph of f by hand and use DERIVE to check your answer.

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Microsoft Excel in the mathematics classroom: A case study

Fathiya Khamis Al Rawahi, Sameen Ahmed Khan and Abdul Huq

Department of Mathematics and Applied Sciences, Middle East College of Information Technology, Muscat, Sultanate of Oman

Abstract

Microsoft Excel is a wonderful application that can be used to achieve student learning outcomes. Bringing visual, hands-on exercises into the learning process has turned students from almost passive spectators into active participants. Exploitation of a powerful spreadsheet-oriented technique in teaching, that re-inforces mathematical concepts, has further enabled us to integrate information technology into the mathematics curricula. In this paper, we discuss our 'experiments' with Excel in several mathematics courses including calculus courses.

Introduction

In any introductory mathematics course designed for non-mathematics majors, it is important for the student to understand and apply mathematical ideas in a variety of contexts. With the increased use of advanced software in all fields, it is also important for the student to interact effectively with the new technology. With the goal of integrating these two objectives, we have used Microsoft Excel in our teaching.

Microsoft Excel is a simple yet versatile application that can be used to achieve student learning outcomes. Bringing visual, hands-on exercises into the learning process can turn students from almost passive spectators into active participants. Exploitation of a powerful spreadsheet-oriented technique in teaching, by re-inforcing mathematical concepts, enables us to integrate information technology into the mathematics curriculum. In the last few semesters we have covered a wide range of topics using Microsoft Excel. Ours is a support department with students doing basic courses in mathematics and statistics in a typical undergraduate programme.

We chose Microsoft Excel because it is the most widely known and probably the most commonly used application. Using Excel can enhance understanding of the content with a graphic presentation of the information. It provides a visual representation of data that makes it easier to analyse. Excel reduces the difficulty of processing and plotting data and allows students a means for interpreting the results. Excel has another advantage in that it is widely used outside mathematics. Students of accounting, business, finance, and certain other disciplines usually have some experience with Excel before they take a course in mathematics.

In this article, we shall briefly look at the history of spreadsheets. Then we shall describe our experience of using Microsoft Excel in the various undergraduate courses. Finally, we summarise the learning outcomes and the difficulties we experienced and briefly mention some of the topics we shall be covering in the forthcoming semesters.

Spreadsheets

Spreadsheets have been used by accountants for hundreds of years (Power, 2004). Computerised or electronic spreadsheets are of a much more recent origin. In the realm of accounting jargon, a spreadsheet was and is a large sheet of paper with columns and rows that organises data about transactions for a business person to examine. It spreads or shows all of the costs, income, taxes, and other related data on a single sheet of paper for a manager to examine when making a decision. An electronic spreadsheet organises information into software-defined columns and rows. The data can then be 'added' by a formula to give a total or sum. The spreadsheet program summarises information from many paper sources in one place and presents the information in a format to help a decision maker see a more complete picture. The first electronic spreadsheet, VisiCalc, appeared in 1979 (Bricklin and Frankston, n.d.). It was created by Dan Bricklin and Bob Frankston for the Apple-II platform. It was conceived and developed as a tool to do repetitive calculations for Bricklin's studies at Harvard Business School. The name VisiCalc is a compressed form of the phrase visible calculator. The basic paradigm of an array of rows and columns with automated updates and display of results has been extended with libraries of mathematical and statistical functions, accompanied with powerful graphing facilities.

Microsoft Excel was one of the first spreadsheets to use a graphical interface with pull-down menus and a point and click capability using a mouse pointing device. The Microsoft Excel spreadsheet with a graphical user interface makes it very attractive for users. Moreover, Microsoft Excel has established itself as a ubiquitous program. This is one more reason why we chose to use Excel in preference to certain other costly packages. This spreadsheet enables a middle course compared to the extremes of fully coding an algorithm in some programming language (such as FORTRAN or C++) and using a ready-made package. The spreadsheet approach is perhaps more suited for learning. Moreover, Excel has a highly developed graphical interface.

Numerical methods with Microsoft Excel

We did several numerical calculations using Microsoft Excel, in a range of topics including matrices and calculus. In the three figures we show screenshots of the actual work performed by our students.

Results and Conclusion

Our students unanimously expressed an interest in using Microsoft Excel compared to analytical calculations and calculator-based numerical methods. More than three-fourths of the students could execute the tasks described in the previous section. Excel is readily available on most of our computers. This saved us from incurring additional

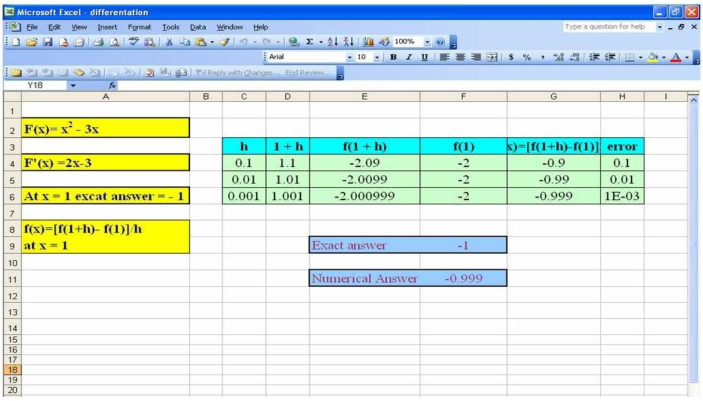

Figure 1: Numerical differentiation.

costs in buying additional software. The students could plot more graphs and solve a much larger number of problems than they would have done otherwise.

We faced certain difficulties. Some of the students were slow at typing and there were others who made mistakes in entering the data. Some of the students were slow at the beginning in some ways such as, getting use to the '=' sign in the formula, or how to make the equation work within the cells of the columns. Some students highlighted the wrong set of data. One of the most serious mistakes that students often made was to believe whatever the computer churns out. This can be overcome by making them realise the importance of checking Excel-generated results for a few values using traditional methods.

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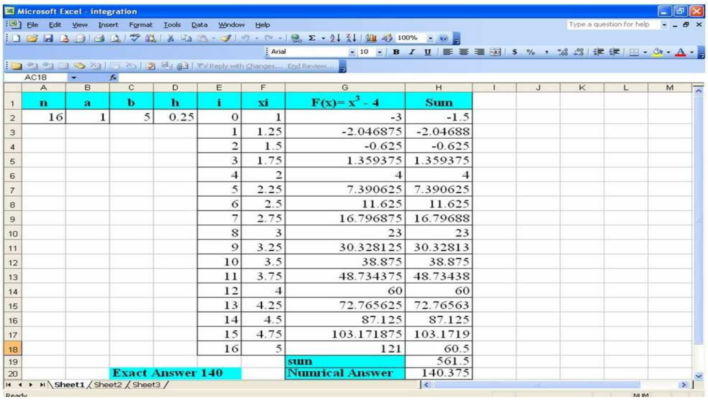
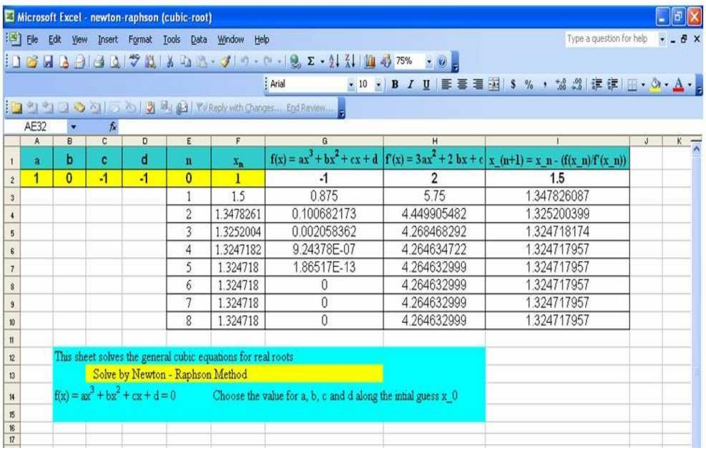


n	a	b	h	i	xi	F(x)= x^3 - 4	Sum
16	1	5	0.25	0	1	-3	-1.5
				1	1.25	-2.046875	-2.04688
				2	1.5	-0.625	-0.625
				3	1.75	1.359375	1.359375
				4	2	4	4
				5	2.25	7.390625	7.390625
				6	2.5	11.625	11.625
				7	2.75	16.796875	16.79688
				8	3	23	23
				9	3.25	30.328125	30.32813
				10	3.5	38.875	38.875
				11	3.75	48.734375	48.73438
				12	4	60	60
				13	4.25	72.765625	72.76563
				14	4.5	87.125	87.125
				15	4.75	103.171875	103.1719
				16	5	121	60.5
						sum	561.5
		Exact Answer 140				Numrical Answer	140.375

Figure 2: Numerical integration.



a	b	c	d	n	x_n	f(x) = $ax^3 + bx^2 + cx + d$	f'(x) = $3ax^2 + 2bx + c$	x_(n+1) = x_n - (f(x_n)/f'(x_n))
1	0	-1	-1	0	1	-1	2	1.5
				1	1.5	0.875	5.75	1.347826087
				2	1.3478261	0.100682173	4.449905482	1.325200399
				3	1.3252004	0.002058362	4.268468292	1.324718174
				4	1.3247182	9.24378E-07	4.264634722	1.324717957
				5	1.324718	1.86517E-13	4.264632999	1.324717957
				6	1.324718	0	4.264632999	1.324717957
				7	1.324718	0	4.264632999	1.324717957
				8	1.324718	0	4.264632999	1.324717957

This sheet solves the general cubic equations for real roots

Solve by Newton - Raphson Method

f(x) = $ax^3 + bx^2 + cx + d = 0$ Choose the value for a, b, c and d along the intial guess x_0

Figure 3: Newton–Raphson method.

Mathematics for electrical engineering programmes: An engineering perspective

Fahar G. Hayati and Anas N. Ali

Faculty of Engineering, Ajman University of Science and Technology, Ajman, United Arab Emirates

Abstract

This paper introduces the problems associated with content, timing, and delivery of mathematics courses to electrical engineering undergraduate programmes within the Faculty of Engineering at Ajman University of Science and Technology. A case study is presented whereby, through a survey, the mathematics courses are assessed by both lecturers and senior students from the Department of Electrical Engineering. Some recommendations are provided to enhance these mathematics courses in order to satisfy the programmes' objectives. This work, however, is still in its initial phase and can be developed through further case studies.

Introduction

Mathematics plays a central part in the formation of engineers, and more so in the case of electrical engineers. There is a set of questions facing engineering mathematics education (see, for example, Kent and Noss (2003)), namely, what kind of mathematical knowledge do engineers require? When and how should mathematics be taught? What is the effect of computer technology on mathematics? All these questions are becoming relevant as engineering education goals and objectives change, as defined by ABET[1] and based on the Engineering Criteria 2000 (ABET, 2005). To satisfy the ABET electrical engineering programme criteria, graduates must have a knowledge of probability, statistics, differential equations, integral calculus, linear algebra, complex variables, discrete mathematics, basic sciences, and engineering sciences necessary to analyse and design complex electrical and electronic devices, software, and systems containing hardware and software components.

Inadequate mathematical skills present a widespread problem throughout engineering undergraduate programmes, however, specific well-documented examples of student difficulties are often lacking, and the exact nature of the difficulty is frequently uncertain. Moreover, there is often little communication between engineering and mathematics faculty addressing mathematical skill-related issues. Engineering faculty assume that certain concepts are taught in the mathematics courses, but they are often

[1] Accreditation Board for Engineering and Technology, based in the US.

not familiar with the specifics of the mathematics curriculum, or the methods utilised (for example the terminology and context of use). The goal is to have the available resources and linkages with mathematics courses clearly laid out for engineering lecturers and students alike. This awareness will allow engineering lecturers to build upon previous mathematical learning, rather than attempt to re-teach skills in their own way (Willcox, 2004).

The obvious fact is that most engineering courses depend heavily on mathematics. Therefore, for mathematics to be effective in electrical engineering programmes, it must be delivered properly and must be given at the right time and in the right dose. Hence, the objectives of this work are to focus on the problems associated with the content, timing, and delivery of mathematics courses, and to see their effect on a student's competence in mathematics. As a case study, the mathematics courses within the electrical engineering programme of the Faculty of Engineering at Ajman University of Science and Technology (AUST) was considered. Some practical recommendations are also provided to enhance these courses so that they satisfy the programme objectives.

The research methodology adopted in this work is based on surveys conducted on lecturers from the Department of Electrical Engineering and on senior students. The objective was to obtain feedback on the present mathematics courses offered in the electrical engineering programme, then to analyse and determine deficiencies in these courses in terms of contents, timing, and delivery. Feedback was obtained through two evaluation questionnaires; one by the lecturers and the other by the students. The questionnaires covered the following: (i) mathematics curriculum, (ii) student competence in mathematics, and (iii) teaching and assessment of mathematics. For each statement there were three choices reflecting the level of satisfaction, namely, AGREE, MARGINALLY AGREE, and DISAGREE. The survey covered twenty lecturers and eighty students.

Mathematics curriculum

Present mathematics courses are spread over five consecutive semesters and cover all topics that are relevant to engineering. But, there is a feeling within the Faculty of Engineering that some of these courses contain topics that were taken at secondary school and that they are of little relevance to modern engineering requirements, especially with the onset of information technology software. In addition, many of the lecturers discover from teaching electrical engineering courses that the students have been given the topics in mathematics courses at very early stages, and by the time these topics are needed at senior courses, the students have usually forgotten them. This poses the question as to whether such courses should be offered at a later stage, or even be given within the electrical engineering courses themselves.

The aim here is then to see whether the current mathematics curriculum satisfies the programme objectives. This can be achieved by observing the syllabi, the number of courses, and the timing of the mathematics courses. Table 1 depicts the lecturers feedback on whether these courses meet the engineering requirements. We can see that the majority agree that it does, but the results also imply that there is room for revision. One suggestion would be to reduce the number of courses from five to four, which is agreed on as seen in Table 2.

Lecturer Feedback	Percentage
Agree	42
Marginally agree	32
Disagree	26

Table 1: The present five mathematics courses meet current engineering requirements.

Lecturer Feedback	Percentage
Agree	70
Marginally agree	0
Disagree	30

Table 2: The present five mathematics courses should be revised and reduced to four courses.

With regard to the timing of the mathematics courses within the electrical engineering programme, it can be seen from Table 3 that about half of the lecturers think revision is needed in this aspect. One suggestion would be to transfer some of mathematics topics (for example Fourier analysis, Laplace transforms, etc.) from mathematics courses to core electrical engineering courses (Signals and Systems, Control Systems, Communication Theory, etc.). This solution seems acceptable to the lecturers, as noted in Table 4.

Lecturer Feedback	Percentage
Agree	37
Marginally agree	16
Disagree	47

Table 3: The timing of mathematics courses in the first five semesters of the programme is inappropriate and should be revised.

Lecturer Feedback	Percentage
Agree	70
Marginally agree	10
Disagree	20

Table 4: Some mathematics topics should be dropped and the remainder transferred to core electrical engineering courses.

As stated earlier, some of the mathematic topics learnt by students in calculus courses are a repetition of what they took at secondary school. This is confirmed by our senior students, as depicted in Table 5. Having observed this, it becomes necessary to revise the syllabi of these courses in order to rectify this problem.

Student Feedback	Percentage
Agree	56
Marginally agree	33
Disagree	11

Table 5: The topics you learnt in calculus courses were, to a greater extent, a repetition to what you studied at secondary school.

Students' competence in mathematics

It is observed by faculty that students coming from secondary school have grades in mathematics that seem to be somewhat inflated, and their score in fact does not reflect their true competence in mathematics. Also, there is a notion amongst the lecturers that their students are often incapable of applying mathematical concepts to engineering problems.

In this section we want to observe the effect of the mathematics courses on a student's ability to apply the learnt topics to solving engineering problems. Tables 6 and 7 clearly indicate that students lack the understanding of the physical meaning of mathematical operations and their application in engineering. This is partially due to the delivery methodology employed by mathematicians, where they tend to give preference to abstract mathematics rather than applied mathematics. Having said that, the lack of engineering examples within mathematics courses, as confirmed in Table 8, may increase this deficiency among students. In addition, it has noted from experience that students tend to comprehend mathematics topics better when taught and applied within electrical engineering courses. This is confirmed by the students, as seen in Table 9.

Lecturer Feedback	Percentage
Agree	85
Marginally agree	5
Disagree	10

Table 6: We seldom find engineering students who appreciate the physical meaning of mathematical operations.

Lecturer Feedback	Percentage
Agree	95
Marginally agree	5
Disagree	0

Table 7: Present engineering students lack the competence in using mathematics for solving engineering problems.

Student Feedback	Percentage
Agree	59
Marginally agree	20
Disagree	21

Table 8: In mathematics courses, you were not given enough examples on engineering problems.

Student Feedback	Percentage
Agree	53
Marginally agree	28
Disagree	19

Table 9: You understood some mathematics topics better through electrical engineering courses rather than mathematics courses.

It is noted that when there are so many students with poor mathematical skills, enabling students to utilise mathematical software efficiently could help them enormously. In order to use computers effectively, appropriate software that supports the goals and philosophy of teaching, enhances the curriculum, and helps students should be selected. From Table 10 it can be seen that students lack the ability to use mathematical software in engineering applications, which is mainly due to its limited usage in mathematics courses.

	Lecturer feedback Percentage	Student feedback Percentage
Agree	80	72
Marginally agree	10	21
Disagree	10	7

Table 10: Students cannot use mathematical software in engineering applications.

As mentioned earlier, students' high scores from secondary school mathematics is not a true reflection of their skill in mathematics. This observation is supported by most lecturers as seen in Table 11. The authors suggest that for students to enrol in any electrical engineering program, they must pass an entrance test in mathematics. This suggestion is again agreed on by the majority of lecturers (see Table 12).

Lecturer Feedback	Percentage
Agree	70
Marginally agree	25
Disagree	5

Table 11: Students' high scores in secondary school mathematics seem excessive and are not a true reflection of their skill in mathematics.

Lecturer Feedback	Percentage
Agree	55
Marginally agree	35
Disagree	10

Table 12: Students enrolling in electrical engineering programmes should be made to pass an entrance test in mathematics.

Teaching and assessment of mathematics

To raise a student's competence and appreciation of mathematics, it is required that mathematics courses be taught by applied mathematicians and supported by engineers. Moreover, assessment of mathematics should be based on objectives and outcomes related to engineering applications. Table 13, 14 and 15 show that lecturers' agreement on these requirements is high.

Lecturer Feedback	Percentage
Agree	90
Marginally agree	10
Disagree	0

Table 13: All mathematics courses should be taught to students by applied mathematicians and/or engineers.

Lecturer Feedback	Percentage
Agree	90
Marginally agree	10
Disagree	0

Table 14: Apart from basic Math I and Math II, engineering mathematics should be taught by engineering faculty.

Lecturer Feedback	Percentage
Agree	75
Marginally agree	15
Disagree	10

Table 15: Engineers should be responsible for and run mathematics tutorials.

Finally, regardless of the affiliation of the mathematics lecturer, it is imperative that the engineering faculty be responsible for managing and monitoring mathematics teaching. This is unanimously agreed on by all the lecturers as noted in Table 16.

Lecturer Feedback	Percentage
Agree	100
Marginally agree	0
Disagree	0

Table 16: Engineering faculty should be responsible for managing and monitoring mathematics teaching regardless of the affiliation of the teacher.

Conclusion

This work has looked at the problems associated with the content, timing, and delivery of mathematics courses within the electrical engineering programs in the Faculty of Engineering at AUST.

Based on surveys conducted with both lecturers and students, the following conclusions can be drawn. Firstly, present mathematics courses cover all topics that are relevant to engineering, but there is room for curriculum development in terms of reducing the number of courses and the timing of some courses and topics. Secondly, the engineering faculty seem aware of the weaknesses in the mathematical skills of engineering students, however, the incompetences the students show in applying mathematics in engineering, despite their high scores, indicates deficiency in course delivery and assessment. This might be attributed to lack of understanding of the engineer's needs. In addition, students' understanding of mathematics is all in abstract form without any understanding of practical applications. Finally, applied mathematicians and engineers must collaborate in managing, delivering, and assessing mathematics.

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Science

The effect of ICT on students' achievement in biology

Mohd Zamri Haji Ismail and Bob Chui-Seng Yong

Department of Science and Mathematics Education, Sultan Hassanal Bolkiah Institute of Education, Universiti Brunei Darussalam, Gadong, Brunei

Abstract

The present study investigated the effect of ICT on students' achievement in biology. The sample consisted of 215 Form 4 students in a secondary school. A biology topic on the Human Digestive System was chosen for the study and it was taught to two groups of students using ICT and traditional methods of teaching for four weeks. A paper and pencil test, which consisted of twenty-five multiple-choice questions, was used to measure students' knowledge of digestion before and after the topic was taught. Each question also had four statements to measure their confidence level in answering the questions. Results showed that both methods of teaching significantly improved students' achievement and their confidence level. However, there were no significant differences in students' achievement and confidence level between students who were taught using ICT and those taught using the traditional method. Both treatments seemed to be equally effective in improving students' achievement and confidence level. Implications of this study are discussed.

Introduction

The infusion of Information and Communication Technology (ICT) into teaching and learning has generated much interest in educational research in recent years. ICT has the potential of providing an alternative and more effective teaching and learning tool in education. A vast array of instructional strategies using ICT have been carried out in research studies and they include simulations (Pfahl, Laitenberger, Ruhe, Dorsch and Krivobokova, 2004), online learning (Hanafi, Zuraidah, Rozhan and Mohd Zubir, 2003; Rosseni, Aidah, Mohamed Amin and Zalizan, 2003), static and animated modes of presentation (Sadiah, 2003; Sharifah, Sadiah and Ahmad, 2001), Internet and World Wide Web (Finger, 2003; Seal and Przasnyski, 2001), Multimedia software (Aguilar, Arena, Clarin, Halamani and Montrade, 2003; Hussien, Sadiq and Khalid, 2003; Keong, 2003; Norizan, 2003; Sidhu, Ramesh, Selvanathan and Singh, 2003; Watters and Diezmann, 2003), and Microsoft Excel (Munirah, Shafia and Zurida, 2003).

Evidence emanating from research literature suggests that ICT has a powerful and significant impact on education both in terms of students' affective and cognitive outcomes. Osborne and Hennessy (2001) reported that ICT enhances the effectiveness of

information presentation and also stimulates students' interest. Ngai and Chan (1997–1998) reported that the use of interactive multimedia technology to learn principles of biological techniques, for example rat dissection, was found to enhance student motivation for further learning. Similarly, Lawless, Brown and Cartter (1997) reported that teaching secondary school students about Lyme disease using instructional video significantly impacted on their attitudes about the disease. Sadiah (2003) and Sharifah et al. (2001) reported that students provided with the animated mode of lesson presentation using PowerPoint not only improved students' performance but also enhanced interest in learning biology. Yu (1998) used a computer-assisted instruction and found that it increased students' performance and attitudes towards science. Soyibo and Hudson (2000) reported that post-test attitudes towards biology of an experimental group taught using computer-assisted instruction, were significantly better than those of the control group, taught using lecture and discussion methods. In mathematics, Jabaidah (2002) found that primary pupils were more motivated to learn fractions using ICT.

Numerous studies have also shown that students' academic achievement improved when ICT was integrated in the learning experience. For example, logo programming, computer-assisted instruction (CAI), micro-worlds, algebra and geometry software were found to be effective in facilitating mathematics achievement (Hillel, Kieran and Gurtner, 1989; McCoy, 1996; Simmons and Cope, 1993). In a study, Kulik (1994) reported that students who used computer-based instruction scored at the 64th percentile on tests of achievement compared to students in the control conditions without computers who scored at the 50th percentile. Sivin-Kachala (1998) reviewed 219 research studies from 1990 to 1997 to assess the effect of technology on learning and achievement and reported that students in technology-rich environments experienced positive effects on achievement in all subject areas. In science, Othman, Matthews and Secombe (2005) carried out a research study to test the effectiveness of computer-animated instruction (CAnI) to conventional lecture-based instruction (CLI) in electrochemistry. They reported that students taught using CAnI performed significantly better in achievement than those taught using CLI. In biology, Soyibo and Evans (2002) reported that students taught using CAI significantly outscored the control groups in the post-test in biology achievement.

Various explanations have been put forward with regard to the cognitive benefits provided by ICT in enhancing students' conceptual understanding. Selinger (2004) claimed that ICT can improve the quality of education because multimedia content helps to illustrate and explain difficult concepts in ways that were previously inaccessible through traditional teaching resources and methodologies. Similarly, Ferrer (2002) reported that the use of a multimedia approach using interactive CD-ROMs, PowerPoint presentations and graphing software has been successful in generating conceptual understanding in students. Lux and Davidson (2003) believed that the use of animations were better compared to static illustrations in enhancing students' conceptual change and connecting the concrete animated presentation to the abstract conceptual processes. Other studies have also reported the use of different multimedia in bringing about conceptual change. For example, Munirah *et al.* (2003) on learning mathematics using word processing and spreadsheets, Chandra (2002) on learning about change in seasons using a database, Sharifah *et al.* (2001) on learning biology using PowerPoint, Watters and Diezmann (2003) on science using CD-ROM educational software and

simulation, and Roger and Wild (1994, 1996) on learning science using data loggers.

Hence, it is incontrovertible that the potential benefits of using ICT in teaching and learning is immense. The use of ICT has greatly transformed the outcomes of teaching and learning experiences in the classroom. It does not only supplement and/or complement teacher instructional processes but also offers unlimited access to knowledge and information that is readily available through the Internet. Another benefit is that teachers who use computers in teaching were found to have an increased confidence level in teaching (Gilmore, 1995).

Despite ICT facilities being available in schools in Brunei Darussalam, the traditional forms of teaching among science teachers is still prevalent. The main reason for this continuing trend is because teaching is very much examination-oriented and covering the syllabus remains a teacher's top concern. As a consequence of this practice, learning science becomes less meaningful to students due to a lack of conceptual understanding. This in turn may affect their achievement in science. In studies recently carried out, Yong (2003a, 2003b) reported that achievement in biology at the General Certificate of Education (GCE) Ordinary level (O-level) for the past few years was less than 45 per cent. He reasoned that language problems in learning biology and students' attitudes towards learning biology were partly responsible for the low achievement in biology.

As numerous studies have shown that students' achievement in learning science improves when they are taught using ICT, the present study attempts to investigate the effect of ICT on students' achievement in biology. More specifically, the study focuses on the following research questions:

1. Are there any significant differences in students' achievement in biology between those who are taught using ICT and those who are taught using the traditional method of teaching?

2. Are there any significant differences in students' confidence level in answering the test questions in biology between those who are taught using ICT and those who are taught using the traditional method of teaching?

3. Are there any associations between students' achievement and their confidence level in answering the test items in both groups of students?

Methodology

Sample

The sample of this study consisted of 215 Form 4 students chosen from nine intact classes in a secondary school situated in the Brunei-Muara District. Of the sample, 97 were males and 118 females. All the students in the nine classes took biology as one of their science subjects. For the purpose of this study, five classes ($N = 122$) were taught using ICT and four classes ($N = 93$) were taught using the traditional method of teaching.

Pre-Test on Digestive System (Pre-TDS) and Post-Test on Digestive System (Post-TDS)

The pre- and post-teaching tests consisted of twenty-five multiple-choice questions where each question was provided with four optional answers (one correct answer and

three distracters). For each question, there were another four statements that students had to choose to indicate their confidence level in answering the question. They were as follows:

1. I am 100% confident that my answer is correct.
2. I think I am correct.
3. I think I am wrong.
4. I am 100% confident that my answer is wrong.

Two sets of marking scheme were used: (i) correct answers of students were given one mark and wrong answers were given zero marks regardless of their confidence level (actual score); (ii) answers that take into account students' confidence level using the four-point confidence level as shown in Table 1.

		Four Points Coding
QR	Confidence Rating	Code
C	100% confident I am correct	4
C	I think I am correct	2
C	I think I am wrong	−1
C	100% confident I am wrong	−2
C	No response	0
W	100% confident I am correct	−2
W	I think I am correct	−1
W	I think I am wrong	1
W	100% confident I am wrong	2
W	No response	0

QR = Response to question, C = Correct answer, W = Wrong answer

Table 1: Codes for integrating confidence into marks.

Analysis

The students' learning outcomes were determined in terms of the difference in marks they obtained in the pre- and post-tests. The two sets of marking schemes for pre- and post-tests were compared in order to find out if there were significant differences in their achievement. The idea of including the confidence level was to find out whether students really understood the concepts or they were just plain guessing and got the answer right by chance.

Research design

A biology topic on the Human Digestive System was chosen for the study as it is a common topic found in the syllabi for Biology (5090), Combined Science Biology (5129) and Doubled Science Biology (5134/5135). Only some parts of the topic were used in the study and they included human alimentary canal, mechanical and physical digestion (chewing and peristalsis), chemical digestion, absorption and assimilation.

Students in the ICT group were taught using a PowerPoint program saved to CD-ROM. The PowerPoint presentation included animated pictures and annotations, video clips and online website links. Students in the traditional group were taught using an overhead projector and transparencies, a whiteboard, textbooks, models and posters.

The study involved three biology teachers who had been teaching these classes. The teachers were briefed with the teaching procedure: the content of knowledge to be taught to students and the amount of time allocated to each class so that each group was given the same amount of exposure in terms of content and time. A total of four lessons, each lasting for one hour, were conducted for each class. This was deemed sufficient and is in accordance with the standard practice with this type of study. As suggested by Kokkotas and Vlacos (1998), under carefully controlled experimental procedures, four sessions are adequate for testing hypotheses when teaching a specific domain of knowledge to mature students or subjects. In addition to the four sessions, another two 2-hour sessions were included; one was for administering the pre-test before the intervention, and the other was for administering the post-test after the intervention.

Results and discussion

Research Question #1: Are there any significant differences in students' achievement in biology between those who are taught using ICT and those who are taught using the traditional method of teaching?

Pre- TDS (Pre-Test on Digestive System)
In terms of students' achievement before intervention, the results in Table 2 show that the traditional group has a higher mean score of 33.6 per cent in the pre-TDS than the ICT group (31.6%). However, statistically there are no significant differences in the test performance between the two groups of students. This indicates that students' existing prior knowledge of the digestive system between the two groups were comparable before treatment.

Test	ICT		Traditional			
	Mean	SD	Mean	SD	t-value	p
Pre-TDS	31.6	12.0	33.6	12.7	-1.10	0.26

ICT group, $N = 122$; Traditional group, $N = 93$.

Table 2: Means, standard deviations, and t-value of Pre-TDS for the two groups.

Post-TDS (Post-Test on Digestive System)
The results in Table 3 show that the mean score obtained by the ICT group is slightly higher (51.6%) than those obtained by the traditional group (50.1%) in the Post-TDS. Both groups of students show a tremendous improvement in their test scores after the intervention. Statistically, there are no significant differences in students' achievement in the Post-TDS between ICT and traditional groups.

Initial analyses of students' achievement between pre-TDS and post-TDS for each group revealed that both approaches showed significant improvement in their test performance (Table 4). This suggests that both methods of teaching are equally effective

Test	ICT		Traditional			
	Mean	SD	Mean	SD	t-value	p
Post-TDS	51.6	17.5	50.1	19.6	0.60	0.55

ICT group, $N = 122$; Traditional group, $N = 93$.

Table 3: Means, standard deviations, and t-value of Post-TDS for the two groups.

in improving students' conceptual understanding of the human digestive system.

Method	Pre-TDS		Post-TDS			
	Mean	SD	Mean	SD	t-value	Effect Size
ICT	31.6	12.0	51.6	17.5	-13.9^{***}	1.34
Traditional	33.6	12.7	50.1	19.6	-9.9^{***}	1.01

ICT group, $N = 122$; Traditional group, $N = 93$; $^{***}p < 0.001$.

Table 4: Mean, standard deviation, and effect sizes of Pre-TDS and Post-TDS for the two groups.

Table 5 shows the results on the analysis of covariance (ANCOVA) to find out if there are any significant differences in achievement between students in the ICT group and the traditional group. In the analysis, method of teaching (MOT: ICT or traditional) was set as a fixed factor and the dependant variable was the Post-TDS test with the Pre-TDS test acting as a co-variate.

Source	Type III SS	df	MS	F	P
MOT	470.244	1	470.2	1.891	0.171

ICT group, $N = 122$; Traditional group, $N = 93$;
SS = Sum of squares, MS = mean square.

Table 5: ANCOVA for the effect of method of teaching on students' achievement.

It can be seen that although both methods of teaching significantly improved students' achievement as measured by their performance in the Pre-TDS and Post-TDS, the results obtained by ANCOVA, however, reveal that there were no significant differences in students' achievement between the two methods of teaching whether using ICT or a traditional method.

Research Question #2: Are there any significant differences in the students' confidence level in answering the test questions in biology between those who are taught using ICT and those who are taught using the traditional method of teaching?

Pre-Test on confidence level in answering question (Pre-TCLAQ)
The results in Table 6 show that both groups of students have the same confidence level in the pre-TCLAQ with a mean score of 9.4 for the ICT group and 9.3 for the

traditional group respectively. Statistically, there were no significant differences in their confidence level in answering the questions between the two groups of students. This indicates that the students' confidence level in answering the questions was the same before the treatment.

Test	ICT		Traditional			
	Mean	SD	Mean	SD	t-value	p
Pre-TCLAQ	9.4	10.0	9.3	11.2	0.08	0.937

ICT group, $N = 122$; Traditional group, $N = 93$.

Table 6: Means, standard deviations, and t-value of Pre-TCLAQ for the two groups.

Post-Test on confidence level in answering question (Post-TCLAQ)
The results in Table 7 show that the traditional group has higher mean scores (24.0) than the ICT group (22.0). However, there were no significant differences in the students' confidence level in the post-TCLAQ between the two groups of students.

Test	ICT		Traditional			
	Mean	SD	Mean	SD	t-value	p
Post-TCLAQ	22.4	19.7	24.0	22.0	−0.546	0.586

ICT group, $N = 122$; Traditional group, $N = 93$.

Table 7: Means, standard deviations, and t-value of Post-TCLAQ, for the two groups of students.

Table 8 shows the means, standard deviations, and t-values for Pre-TCLAQ and Post-TCLAQ of students measured in terms of their confidence level in answering the questions. The results show that the confidence level of students in both the ICT group and the traditional group improved significantly after teaching. In other words, both treatments are equally effective in improving students' confidence level in answering the test items on the digestive system irrespective of whether they were taught using ICT or a traditional method.

Method	Pre-TCLAQ		Post-TCLAQ			
	Mean	SD	Mean	SD	t-value	Effect Size
ICT	9.4	10.1	22.4	19.7	-7.6^{***}	0.83
Traditional	9.3	11.2	24.0	22.0	-7.4^{***}	0.85

ICT group, $N = 122$; Traditional group, $N = 93$; $^{***}p < 0.001$.

Table 8: Mean scores, t-values, and effect sizes for Pre-TCLAQ and Post-TCLAQ, for the two groups of students.

Table 9 shows the results on the analysis of covariance (ANCOVA) on the effect of method of teaching on the students' confidence level in answering the questions. In

the analysis, the method of teaching (MOT: ICT or traditional) was set as a fixed factor and the dependant variable was the Post-TCLAQ test with Pre-TCLAQ test acting as a covariate.

It can be seen that although both methods of teaching significantly improved the students' confidence level in answering the test questions as measured in the post-TCLAQ, the results obtained by ANCOVA shows that, between the two methods of teaching, there were no significant differences in the students' confidence level in answering the questions.

Source	Type III SS	df	MS	F	p
MOT	143.961	1	143.961	0.403	0.526

ICT group, $N = 122$; Traditional group, $N = 93$;
SS = Sum of squares; MS = mean square.

Table 9: ANCOVA for the effect of method of teaching on students' confidence level in answering the questions.

Research Question #3: Are there any associations between the students' achievement and their confidence level in answering the test items in both groups of students?

Correlation between achievement (Post-TDS) and confidence level (Post-TCLAQ)
Correlation between the students' achievement and confidence level was measured by their performance in the post-TDS and their confidence level in post-TCLAQ. The results show that there are significant positive correlations between the post-TDS and post-TCLAQ marks for both the ICT and the traditional groups (see Table 10). This means that in both groups, the students' achievement was greatly affected by their confidence level, or in other words, the students' achievement increases as their confidence level in answering the questions increases.

Method	r	p
ICT	0.69	0.000^{***}
Traditional	0.79	0.000^{***}

$^{***}p < 0.001$ (2-tailed).

Table 10: Correlation (Pearson product moment) between the Post-TDS and the Post-TCLAQ.

Conclusion

The present study has generated some interesting findings concerning the benefit of using ICT in teaching a biology topic as compared to the traditional method of teaching. Results indicated that both methods of teaching significantly improved students' performance on the achievement test and their confidence level in answering the questions after the intervention. However, there were no significant differences in students'

achievement and confidence level when the students who were taught using ICT were compared to those taught using traditional methods. Both methods of teaching seemed to be equally effective in enhancing students' conceptual understanding of the digestive system as well as improving their confidence level in the test.

The fact that there were no significant differences in students' achievement and confidence level between the two groups cast some doubts on the benefit of ICT when students are briefly exposed to this method of teaching. Findings in this study seemed to suggest that using ICT to teach a particular biology topic will not result in better learning outcomes than one which uses the traditional method of teaching. One possible explanation is that students may not have sufficient time to adapt to this new method of teaching and hence are unable to make full benefit of it when the lessons are taught using ICT. Another possible explanation is that there is very little difference between using a PowerPoint presentation and overhead transparencies as both methods are teacher-centred except that there is the possibility of incorporating some animations in the lessons using ICT.

The teaching and learning of biology could be made more meaningful if the lesson presentation using PowerPoint is supplemented with other activities to reinforce understanding of the concepts learnt. There are many software packages readily available which can be provided to the student to allow them to absorb the biology concepts at their own time and pace, thus making learning more meaningful.

The impact of ICT on students' learning outcomes will ultimately depend on the biology teachers. They are the ones who will decide how best to impart the knowledge. The use of ICT will undoubtedly bring new, exciting, and rewarding educational experiences for both students and teachers alike. The immense benefits of integrating ICT in education have yet to be fully explored and hence more research needs to be done in this area before the technology can be effectively integrated into the education system.

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Using the peer instruction method in teaching general physics with Blackboard as a tool

Maamar Benkraouda

Physics Department, United Arab Emirates University, Al Ain, United Arab Emirates

Abstract

This paper shows positive results to support the claim that the best use of lecturing is in combination with other methods. This helps students retain their interest and attention, allows for more student participation, and emphasises different learning styles. The method chosen for this study is the well-established *Peer Instruction Method* which is based on co-operative learning. It helps substantially in the learning process because it encourages students to work together.

Introduction

The most popular and widespread teaching method is lecturing, in which the lecturer gives information and the students are on the receiving end. Despite its historical precedence and efficiency, this kind of teaching, where the presentation is delivered as a monologue in front of a passive audience, complicates the task of getting students involved in the learning process and capturing their attention during the lecture period. The only exception to this is extraordinary lecturers, who are hard to come by. It is even more difficult to provide adequate opportunity for students to critically think through the arguments being developed. Consequently, lectures simply reinforce students' feelings that the most important step in mastering the material is memorisation of equations and examples.

The best use of lecturing is in combination with other methods. This helps students retain interest and attention, allows for more student participation, and emphasises different learning styles.

Peer instruction

To help address this problem in the learning process in introductory physics courses, Eric Mazur, a Physics Professor at Harvard University, has developed a method that he calls 'Peer Instruction' (Mazur, 1997). It involves students in their own learning during the lecture and focuses their attention on underlying concepts. Tests composed of conceptual questions are introduced into the lecture at regular intervals. The questions are

designed to probe the difficulties in understanding the lecture material. The students are given one to two minutes to think about each question and then to formulate their answers. Then, they spend two to three minutes trying to convince their neighbours (two to three students) of their answers. This process forces the student to think further about a concept and try to not only understand it, but also assess the depth of their understanding. All students then attempt another answer to the same test. The first answers give real-time feedback to the lecturer on how much the students comprehended the material, and if needed, how the lecturer should reformulate explanation of the concepts. Systematic studies of the Peer Instruction Method (PIM) have shown significant gains in conceptual understanding as well as a gain in problem-solving skills comparable to those acquired in traditionally taught classes (Crough, Fagen and Mazur, 2002). Dozens of lecturers at other institutions have implemented peer instruction with their own students and found similar results (Fagen, Yang, Crough and Mazur, 2000).

Peer instruction method in teaching general physics at United Arab Emirates University using BlackBoard

In teaching general physics, we thought of using PIM in problem solving to study its effect on the process of learning physics. For data collection, we used BlackBoard for online examinations which were marked automatically.

At the end of each chapter each student took an online examination where they had to a solve a few multiple-choice questions. After submitting their answers, the students were allowed to discuss their answers with their neighbouring classmates for five minutes. Going online again, they answered the same problems before being exposed to the correct answers.

The process of discussion between the students forced them to think about the problems at hand and made them rethink their reasoning and understanding of each problem. The comparison of the two answers indicated how much the discussion had affected the students' understanding of the problems at hand.

Results and discussions

We conducted the peer instruction experiment with a section of twenty-three students. Because of time restrictions and the fact that one had to cover a certain syllabus, the number of quizzes was not as high as it could have been. We are in the process of accumulating a larger data set of quizzes for more adequate statistics. Nevertheless, the graph in Figure 1 shows some important results.

Figure 1 shows the percentage increase in the students' answers before and after the students' discussions for each quiz. This clearly shows that the discussions always lead to a better understanding of the problem and a significant improvement in the students' answers. The figure also shows that the improvement in the answers fell into two categories, one with a slight increase of five per cent and the other with a significant increase of twenty per cent. The slight increase could be due to the fact that either the students did not know how to solve the problem and discussions did not lead to further understanding, or most students knew the right answer and the discussion did not add much to their understanding. The second category fell in the twenty per cent range and

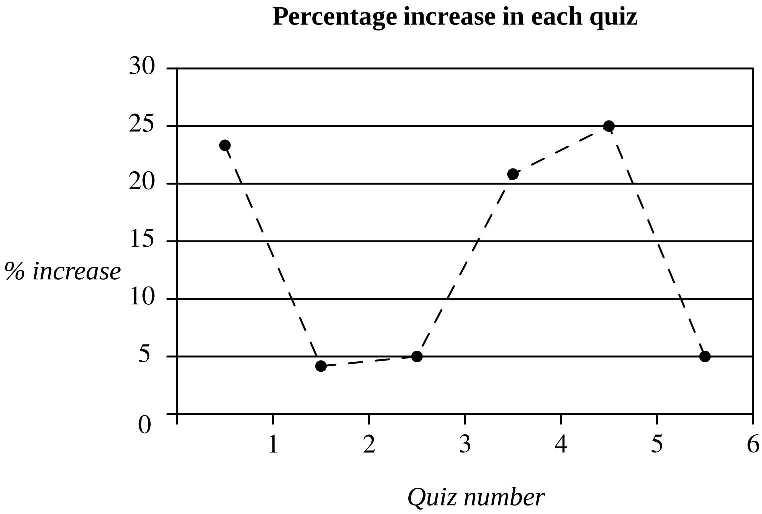

Figure 1: The percentage increase in quizzes after peer consultation.

this clearly shows that the discussions helped a sizable number of students in working out the right answer. This real-time feedback helped us identify where the students found difficulties, where the discussions have helped, and where the same concept has to be approached and explained in different ways when the discussions do not show any improvement in the students' understanding. The challenge, of course, is to come up with the kind of problems that rightly probe the concepts at hand. For a repository of sample conceptual problem questions, Project Galileo (n.d.) is particularly useful.

Several factors in this method have to be further investigated. Some of these factors have to do with the adequacy of the problems to probe the concept at hand. The effect of individual student levels in the group's composition, and how that affects the outcome of the discussions, also needs to be addressed. Time management and technical problems that affect, in one way or another, the learning outcomes of the method have to be optimised. More importantly, the comparison of the achievement of students subjected to PIM in problem-solving skills with students that have learnt through the traditional ways has to be carefully analysed. This will allow one to show unambiguously the impact of PIM in teaching general physics.

Conclusion

We have shown in this study that PIM could help students better understand concepts in general physics. Students' answers to tests were collected through BlackBoard. This gives qualitatively real-time feedback to the lecturer on student level of understanding of concepts and shows how the discussions could engage students in the learning process, as well as have most students understand the lecture material. PIM allows students to approach the concept at hand in a different way without moving on to a new topic until it has been clarified. Further study is needed to collect more meaningful statistics

and a few parameters need to be fine-tuned so as to compare the results of the PIM with the traditional lecture method.

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Universe of knowledge and knowledge of universe

Ildus Nurgaliev

Department of Physics, Timiryazev Academy, Moscow State Agricultural University, Moscow, Russia

Abstract

The modern age endorses new imperatives on education. Reckless exploitation of natural resources will cause irreversible exhaustion of the agro- and bio-potential of the planet during the lifetime of the next few generations. An adequate response to the challenge lays in modern technologies and educating responsible (socially-oriented) professionals. This is why the importance of teaching modern technologies along with providing students with an understanding of global, long term consequences of human industrial activities is growing. How such factors are incorporated into teaching the course ‘Theoretical Foundations of Modern Technologies’ at the Moscow State Agricultural University are discussed.

Introduction

Sustainable development is not, in its broad interpretation, a new idea. Even emerging and disappearing civilisations over the course of human history have recognised the need for harmony between the environment, society and economy. They succeeded or became ruined in correspondence with their ability to follow this idea, specifically in agriculture. What is new nowadays is an articulation of the idea in the context of its global, holistic, and scientific understanding in the current industrial transforming-to-informational societies and unprecedented in human history pressure of the anthropological factor to the biosphere.

The nuances of sustainable development as a concept are different to different people. But the most frequently quoted and commonly percept definition, I believe, is from the report *Our Common Future* (also known as the *Brundtland Report*): ‘Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs’.

Progress in developing the concept of sustainable development has been vivid since the 1980s. In 1992 leaders at the *Earth Summit* built upon the framework of the Brundtland Report to create agreements and conventions on critical issues such as climate change, land erosion and deforestation. They also drafted a broad action strategy; an agenda for the twenty-first century; as well as the working agendas for environment and development issues for the coming decades. Throughout the following years regional

and sectored sustainability plans have been developed. A wide variety of groups, ranging from businesses to municipal governments to international organisations such as the UN institutions, have adopted the concept and given it their own specific interpretations. These activities have deepened our understanding of what sustainable development means within the framework of different viewpoints. Unfortunately, as monitoring showed and as the Earth Summit concluded in 1997, real progress on implementing sustainable development working plans has been slow. The process of developing the strategy was continued.

One may consider 'The Johannesburg Declaration' at the *World Summit on Sustainable Development* in 2002 'to build a humane, equitable and caring global society cognizant of the need for human dignity for all' as a sort of mission statement built on the ten-year-old aspiration expressed as a commitment of world leaders in The Rio Declaration from the World Conference on Environmental and Development 1992, stating: 'Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature'. Another important output of the Johannesburg Summit, instrumental to the present report, was a declaration of education as the foundation of sustainable development. This commitment was earlier embodied formally in Chapter 36 of Agenda 21 of the Rio Summit, 1992.

Education for sustainable development

Education for sustainable development – agriculture and forestry education as a component – has four major forms, pursuing diverse goals and oriented to different categories of audiences: promotion and improvement of basic education (elimination of illiteracy), re-orienting existing education at all levels to address sustainable development (educational reforms), developing public understanding and awareness of sustainability (off-class education, life-long education), and (professional) training.

The UN-driven vision of the role of education is focused mainly on elevating basic education in developing countries. For example, *The Plan of Implementation* establishes the linkages between the *Millennium Development Goals* on universal primary education for both boys and girls, but especially girls, and the *Dakar Framework for Action on Education for All*. The creation of a gender-sensitive education system at all levels and of all types, formal, non-formal and informal, to reach all is emphasised as a crucial component of education for sustainable development. Education is recognised as a tool for addressing critical questions such as rural development, health care, community involvement, HIV/AIDS, the environment, and wider ethical/legal issues such as human values and human rights.

There is no accepted universal model of education for sustainable development. While there will be overall agreement on the main aspects of the concept, there will be nuances according to local contexts, priorities and approaches. Each country has to define its own priorities and actions. The goals, emphases and processes must, therefore, be locally defined to meet the local environmental, social and economic conditions in culturally appropriate ways. Education for sustainable development is both relevant and critical for both developed and developing countries in corresponding manners.

An example from Russia

The Russian Federation has a well developed education system inherited from the Soviet period. The system is currently undergoing a crisis along with economics and society. The crisis, as is analysed in other publications by the author (Nurgaliev, 2003a, 2003b), has two main dimensions: (i) domestic, dealing with economic hardship and lack of support from government, and (ii) global, in the context of common challenges faced by all education systems in responding to the demands of modern development and a globally transforming workplace. In this report a specific development in Russian higher education for agrarian and forestry managers is discussed.

The basics of natural sciences such as Physics, Chemistry and Biology were touted to be agro-industry managers in a new manner some ten years ago at the Moscow State Agriculture Academy (MSAA) named after K. A. Timiryazev.[1] Students of the economics faculty study either ‘Concepts of Modern Sciences’ (economics-oriented specialisation students) or ‘Theoretical Foundations of Modern Technologies’ (production-oriented specialisation students). Both courses are composed of three circles focusing on Physics, Chemistry and Biology. Displacement of the three standard courses of classic Physics, Chemistry and Biology by this integrated course tends to encompass a broader panorama of modern achievements of natural sciences. Integrated courses place emphasis on what tendencies take place in natural sciences and modern technologies and what impact they have on, not only productivity, but also on the fulfillment of the demands of sustainability.

As a lecturer the author builds on the thesis that modern technologies are imminent to sustainable development. In this respect new and renewable energy technologies are milestones for the improvement of the economic, social and environmental quality of the world populations in coming decades in developing countries. And, at the same time, only adapting new technologies such as energy saving, energy conservation and renewable energy use is a response to facing energy shortage for developed countries.

Because of a heavy reliance of modern civilisations, basically Western rather than developing countries, on intensive energy consumption, the accelerated development of technologies for the integration of new and renewable forms of energy will play a crucial role in the realisation of this shared vision. It became obvious to many experts that modern technologies were key in achieving the harmonious coping coming challenges and demands: globalisation, increased efficiency, minimisation of the systems, downsizing energy and natural resource consumption, deforestation. Globalisation is a world scale process, objective and, at the same time, full of contradictions by its consequences. It is of great importance for the modern technology dissemination. It will impose a new quality in the development of new and renewable energy and water supply technologies, particularly. Efficiency has increased instead of using more resources is an everlasting demand for modern technologies. The miniaturisation of the systems for energy conversion has opened a new venue, which is of particular importance for the renewable energy technologies such as wind energy, solar energy, geothermal energy, bio-mass energy. The technology of closed agro-circles has become a new paradigm.

Teaching natural sciences for sustainable development, especially to agro-managers, forestry managers would be decision makers in the field of agro-development, agro-

[1]MSAA was one of the major agro-universities of the former Soviet Union.

business and forest industry is a topic deserving broad and joint discussion by academic communities and by those involved in development, predicting, planning and forming. The traditions of teaching natural sciences and training engineers during the Soviet period provided a successful example and were studied even by Western countries. The elements of the Soviet experience were used in their practices. The first Sputnik served as a symbol of Soviet success. The lack of adoption of the Russian education system to modern realities, such as a market economy and the refocusing of modern economies from extensive natural resources exploitation towards effective sustainable development threatens Russia further losing its geopolitical position. The current policy of Russian Government, which is excessively based on hydrocarbon exports, is not far seeing. As the Johannesburg forum declared for the planet, education is a key sphere approaching the problem of sustainable development on a national scale as well. The course of lectures and seminars 'Concepts of Modern Sciences' and 'Theoretical Foundations of Modern Technologies' held at MSAA is a building block in developing sustainable development oriented agro- and forestry managers education. Each phenomenon, natural law, new technology is, when relevant, discussed from the point of view of natural resources saving, environment protection and sustainable development. As a course requirement, the students prepare research papers and do reports in class. This, in addition to lectures, enables them to encompass broad agenda of issues regardless of a limited amount of class hours.

One critical topic the author as a lecturer and advisor in research paper writing overcomes is negligence and a tradition of ignorance in the Russian institutions in the field of digital copyright. Quite often not only students, but also sometimes quite a few colleagues judge copyright issues very intuitively and casually. Some colleagues 'solve' the problem of plagiarism by demanding handwritten reports. Many students, fortunately, voluntarily choose topics related to sustainable development. The author has prepared a textbook 'Concepts of Physics and Elements of Modern Technologies'. Presented style of teaching physics is based on the belief that this way of using well served old respected traditions of teaching natural sciences along with the elements of modern technologies and sustainable development fits current and coming demands in both Russian and global realities.

Here are a few specific topics of the course and of student research papers: 'Distance (Space) Monitoring of the Planet (Plants)', 'Physics of Renewable Energy Sources', 'Information Technologies in Agriculture and Forestry for Sustainable Development', 'Noosphere Concept by Vernadsky', 'Physics of Computers, Cybernetics in Agriculture', and others.

One branch of modern physics, cosmology, is of special importance in bringing future professionals into broad and deep understanding of concepts on sustainability and scientific world-view. Cosmology gives a culture and its members a fundamental sense of who they are, where they come from, where they are going and what their personal mission is in the broadest context. For example, expanding Copernicus' principle to the cosmological one about the lack of any centre in the Universe, about the ordinary location of our Galaxy, of the Solar system, in the Universe, in our Galaxy, respectively, helps to comprehend the limits of an anthropocentric world-view. One may say that cosmological theory is a system of knowledge about our Universe to explore and explain the sacred or scientific fundamental relationship between the way the world

is and combining this system of knowledge with the aesthetic, moral, and spiritual principles the way human beings should behave. Analysis of state of the art of modern physical cosmology in the course is anticipated by the short overview of mythic and religious conceptions of the different nations, of ingenuous civilisations and major world beliefs such us Christianity, Islam, Judaism, Hinduism and Buddhism, as well as their ancient ecological and sustainability principles. Modern scientific conceptions of formation and evolution of the Universe, Solar System and the Earth, processes and, specifically, time scales of forming different resources on the Earth, bring students to clear understanding of why science-based sustainable development ideas are crucial in the epoch of hyper-intensified resources-wasteful production and consumption.

Conclusion

Summarising, I would conclude that modernisation of teaching natural sciences not only including basics of modern technologies along with basics of classic sciences but also emphasising on harmonious interaction of the technologies with environment is imperative for sustainable development education. We in academia in different countries should share our experiences and innovations in this field to enrich each other for the common good.

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A matrix method of deriving risk assessment for educational chemistry laboratory sessions

P. Rostron

Core Chemistry, The Petroleum Institute, Abu Dhabi, United Arab Emirates

Abstract

A full material safety data sheet contains a vast amount of information about the hazards associated with a particular chemical. We propose a model technique which simplifies this information onto a double-sided A4 page. The first page is an identification of the hazards presented by the experiment, whether they be chemical (reagents, intermediates or products) or instrumental. The second page details the risk reduction protocols that the hazards identified require. Not only does this make particular hazards easier to identify, it is easy for students to appreciate the need for safety equipment and that there is a safe operating procedure that will reduce their risk of accident or injury.

Introduction

In today's society, risk aversion is a very real phenomenon. One only has to look at how governments around the world are banning public smoking to see how aware people are becoming of the hazards in their daily lives. When it comes to teaching chemistry, and particularly chemistry laboratory experiments, non-chemists start to get extremely concerned about the 'risks' they see. We also live in an increasingly litigious society, where one is more likely to face a judge in response to a student's 'accident'. Thus we need to protect ourselves from litigation, promote chemistry as a 'safe' subject and maintain the interest for the students. In this paper we will look at how to assess hazards, perform a risk assessment, and provide a simple summary of the hazards that anyone can read. But first we start with a little background on hazards and risks.

Hazards and risks

These two words are often, mistakenly, considered interchangeable, particularly by non-scientists. However, there are important fundamental differences between hazard and risk. A *hazard* is an inherent danger associated with something, whereas the *risk* is the probability that an accident will occur as a result of that hazard. A hazard is inherent to the substance which does not go away, whereas the use of appropriate measures

can reduce the risk to negligible. For instance, whilst it is possible to drown in five centimetres of water, the probability of that happening is quite remote (you would have to fall face down and be knocked unconscious) and so a five centimetre depth of water is not considered to be a high risk environment for adults. However, water deeper than one's height is, particularly if one cannot swim, and for that reason deep water is usually labelled as 'Danger Deep Water'. Of course, for children, shallow water can become a high risk environment and therefore children must be supervised at all times when in or near water.

The risk of injury can be reduced by either removing the hazard entirely or by using protective measures designed to separate the user from the hazard. A good example might be mains electricity. By sheathing electrical wires with insulation, we separate people from the hazard. However, there is often a cost benefit analysis required. We often require insulation combined with flexibility of movement for electrical cables. Whilst wires tend to have good flexibility, many of the insulation materials do not maintain the same flexibility over the lifetime of the cable, with the consequence that the plastics we use can become brittle, leading to possible electrocution. The solution to cable embrittlement is to ensure that cables are tested according to a schedule of inspection and replaced as necessary.

This highlights one of the major problems with barrier protection methods, in that the risk is reduced only as long as the barrier remains contiguous. It is imperative that an inspection regime, either according to legal requirements or as a manufacturer's recommendation, be set up, and that records of inspections be kept.

Another aspect to consider when assessing risk is what safety equipment is immediately available that can mitigate the consequences of an accident. The proximity of portable fire extinguishers can reduce the consequences substantially and hence the risk associated with a fire starting in a laboratory. Similarly, adequate first aid equipment can help. Of course, it goes without saying that all staff must be trained in the correct application of safety equipment, and that procedures to follow in the event of an incident need to be thought through and planned in advance. For really serious accidents, crisis action plans need to be written, and maybe even practised. The level of preparation for accidents should be in line with the perceived level of risk, otherwise people will waste precious resources on very low probability (say once in a hundred years) events and may even fail to take risk assessment seriously.

Legal aspects

The legal aspect of risk assessment varies from country to country, but there are some general rules that seem to apply to all. In general, a teacher becomes the effective guardian of the students in his or her care. Therefore a simple test is to ask whether one would allow one's own children to do the operation, and how would one supervise them. In addition, it is vitally important that one can show through a sufficiently detailed audit trail that there is a culture of risk assessment at the institution. This can take the form of providing documents showing that all activities are assessed for hazard, that hazard identification materials exist, and that there has been movement to change practices to increased safety. In this day and age it seems to be no legal defence to say that one did not know about a hazard that led to an accident, which tends to be classed as

negligence.

Here in the Middle East, we have a particular concern in the fact that often the courts will apportion blood money damages if negligence can be proved. It is imperative that one can prove that: (i) hazards were identified, (ii) students were instructed in the correct safe operating procedures (SOP), (iii) a culture of risk assessment applies to all laboratory work, and (iv) there was suitable supervision by properly qualified staff.

Hazards in the chemistry laboratory

Bodies of open water are the kind of hazard that we are exposed to in life and we can understand and identify these hazards, but in the chemistry laboratory, we are confronted by hazards that life has never prepared us for. Accidents can occur simply because the victim did not know that the hazard was even there. Therefore, the first task must be to identify the hazards inherent in the experiment. Experimental hazards are extremely varied and the hazard identification should be performed by at least one, and ideally two, trained chemists. Hazards in the chemistry laboratory comprise two types, chemical and instrumental.

Chemical hazards

The first step is to obtain the Material Safety Data Sheet (MSDS), the production of which is a legal requirement in many countries around the world. Many companies now provide these as online catalogues that can be downloaded for free (J. T. Baker is one of many excellent resources). Therefore, there is no excuse for failing to obtain MSDSs for the chemicals in the experiment. An alternative approach is to use information from a dedicated school science advisory organisation. Two excellent options are the Association for Science Education (ASE) and the Coalition of Local Education Authorities Provision of Science Services (CLEAPSS). One can join CLEAPSS for as little as £95 for two years as an overseas member and is well worth the investment.

Instrumental hazards

Many of the instruments and processes in chemistry are novel to most students. They are rarely aware of the skills required to manipulate them safely and must be trained in their correct operation. The only way to plan this training is to identify the hazards involved in the hazard identification process. For each piece of equipment the best working practice should be devised (often a simplification of the operating instructions) and written up as a standard operating procedure. In this way one builds up a complete set of instructions that protect both the student from the machine as well as protecting the machine from the student!

Once the assessment of hazards has been completed, one now turns to the assessment of risk. Unfortunately, because of several factors, such as a basic fear of litigation, many stop here and simply make experiments ‘safe’ by not allowing any hazards into the laboratory.

Risk assessment

A risk assessment is a measure of the probability of harm occurring. There are several factors which must be considered when assessing the level of risk.

- The laboratory layout.
- Availability of safety equipment.
- The type and magnitude of the chemical hazards.
- The type and magnitude of instrumental hazards.
- The quantity of chemicals used.
- The number of times the operation is to be repeated.
- The protection regime employed.
- The frequency of safety inspections.
- Adherence to safety rules.
- The skill level and maturity of the experimenters.
- Training that the teacher has received.

It may sound obvious, but there is more risk of harm from a chemical that requires only 0.05 grams to kill than one that requires 1 gram to produce a fatal dose.

The risk assessment is the difficult part of the whole process, and has to be a professional opinion by the teacher. He or she must analyse the experiment carefully, looking at all of the factors above and come to a decision as to what the level of risk is. Many prosecutions in the United Kingdom have relied upon this. Provided that the teacher works through a risk assessment procedure, identifies the hazards, and develops a protection regime based upon his or her professional opinion, then the teacher historically has not been found guilty of negligence. It is only when experiments are performed without a risk assessment, or that commercially produced risk assessments are used without any consideration of the local circumstances, that successful prosecutions have been achieved.

The problem is that there are so many local factors to take into account that a generic risk assessment is rarely appropriate. This means that we should all get involved in risk assessment, and write down what we instinctively know about safety. One approach which has found merit here is the matrix method, which uses a two page A4 form which is easy to complete (see appendix).

The matrix risk assessment procedure

Step 1
Identify all of the following that are involved in the experiment: (i) starting chemicals, (ii) reaction intermediates, (iii) products, and (iv) instruments.

Step 2

These compounds and procedures are then listed in the first table, and a hazard assessment performed, using the relevant MSDS. Each increase in number is supposed to represent an order of magnitude increase in hazardousness. You use your judgment as a guide. The level of hazard should not be class dependent, since hazards are universal. However, different classes may be exposed to different levels of hazard, depending upon their experience. The following table gives an approximation of how to assign hazard numbers, for the three easiest to classify categories, as an example.

Hazard number	General description	Toxic description	Corrosive/irritant description	Flammable description
0	No significant hazard	No significant hazard e.g. NaCl(s)	No significant hazard e.g. < 0.5M acids and bases	No significant hazard e.g. CH_2Cl_2
1	Low	Harmful $LD_{50} \sim$ 10–50g	Irritant or corrosive e.g.$\sim$1M acids and bases	Flammable e.g. MeOH
2	Medium	Toxic $LD_{50} \sim$ 10g	Severe irritant or corrosive e.g. $\sim$ 1/2 conc. acids bases	Moderately flammable e.g. ethyl acetate, acetone
3	High	Highly toxic $LD_{50} \sim$ 11g	Highly corrosive e.g. conc. acids	Highly flammable e.g. toluene hexane
4	Severe	Pharmaceutically active $LD_{50} \sim$ 100mg	Dilute HF/perchloric acids	Extremely flammable e.g. Diethyl ether
5	Extreme	$LD_{50} \sim$ 10mg	conc. HF/perchloric	Pyrophoric e.g. n-BuLi

This is only intended to be a guide, showing how there is an almost exponential rise in hazard with number. The underlying thought is that this method means that each number has a range of application, allowing for simplicity in operation. However, this does mean that individual cases can be subject to different interpretation of hazard by different people. This is where small groups are so useful in producing risk assessments.

This is actually one of the aims of this method, the flexibility means that it is simple

to perform the hazard identification, yet it is a tool to generate discussion about hazard. Only when people are discussing hazards are they truly aware of them. When this happens, the people involved must discuss the most appropriate classification and come to an agreement.

Step 3
Once the hazards have been identified, the next step is to consider the experimental procedure. Break the experiment up into individual steps and consider the hazards associated with each step. List the highest hazards and the SOPs that are needed.

Step 4
Now one can consider the following factors: (i) quantity of material, (ii) repetition of action, (iii) maturity of class, and (iv) your laboratory facilities. We use these factors to deduce the exposure potential, that is, the probability of harm, coupled with the seriousness of an accident occurring.

As a default minimum, students who handle a H3 or higher hazard can never be assigned a low exposure potential simply because the consequences of an accident will be serious. However, for example, burns caused by the use of a hotplate are quite likely, but the exposure potential is low because the consequences are minor.

The exposure potential assessment is also the time at which the teacher assesses the possibility of replacing a high hazard material with a lower one to reduce the exposure potential. A combination of high exposure potential and high hazard is a recipe for disaster and should be avoided. This can be achieved by substitution of reagent or a reassessment of the procedure.

Step 5
Once the exposure potential is assessed, one finally looks at how to reduce the risk of harm to the student. This is the protection code. The aim here is to use a safe working practice commensurate with the hazards and exposure potential. In the vast majority of cases, this will be achieved by using P1, i.e. an open bench. Note that this means that the work will be performed in a suitable space such as a purpose built chemistry laboratory, equipped with emergency response equipment and alternate fire exits. P1 also implies that the basic laboratory rules are in force.

Step 6
Once this is completed, the teacher performing the risk assessment signs the sheet with the date and makes this available to the students. Currently we do this during the pre-laboratory, giving students time to absorb the material before the laboratory.

Step 7
Finally, a folder containing the following is made available in the laboratory (usually on the teacher's bench) during the experiment: (i) risk assessment, (ii) MSDS for all chemicals, (iii) SOP, and (iv) experimental procedure. The teacher should be able to summon help should the need arise without having to leave the laboratory. There should also be a list of currently certified first aiders as well as procedures to follow in the event of a fire or injury in the laboratory.

Appendix – The matrix risk assessment procedure

Laboratory Hazard Assessment Sheet

NAME	ID No.
DATE	COURSE
EXPERIMENT TITLE / No.	

Hazard Codes: Enter below the correct hazard code

Reagents, Products and Instruments	T	A	F	I	O	W	Other

Hazard Code Classifications	
T = Toxic	C = Carcinogenic
A = Corrosive/Irritant	F = Flammable
R = Radioactive	X = Explosive
O = Oxidising agent	W = Violent reaction with water
G = Liberates toxic gases on contact with water/acid/base	
I = Instrument/glassware/equipment hazard	

Hazard and Exposure Potential Codes

Hazard Category	Number Code
No significant	0
Low	1
Medium	2
High	3
Severe	4
Extreme	5

Exposure potential	Code
Low	X
Medium	XX
High	XXX

Protection Code

Stage	Operation	SOP	Hazard category	Exposure potential	P-Code	Precautions
1						
2						
3						

P-Code Classifi cations
P1 = Open laboratory work (lab-coat and safety glasses)
P2 = Restricted open laboratory (no naked flames)
P3 = Contact protection (lab-coat, safety glasses and suitable gloves)
P4 = Fume cupboard
P5 = Fume cupboard and additional safety (gloves, visor/respirator, etc.)
P6 = Glove box/remote operation

Signatures
I declare that by signing this document, I understand the Chemical Hazards in this experiment and that I will use the protection regime required to minimise the risk. I also declare that no unauthorised experiments will be performed by me. I declare that I understand and will follow all Safe Operating Procedures (SOP) as demonstrated by the teacher.

Student ______________________________ Date ______________________________

Teacher ______________________________ Date ______________________________

Use of the interactive whiteboard in constructivist teaching for higher student achievement

Harkirat S. Dhindsa and Shahrizal Haji Emran

Department of Science and Mathematics Education, Universiti Brunei Darussalam, Gadong, Brunei

Abstract

The aim of this study was to compare the effects of constructivist-informed, technology-rich learning environments and traditional learning environments on students' achievement. The subjects of the study were 115 Form V combined science students (16 to 19 years old) studying in a government school in Brunei. These students were from four intact classes. Two classes (23 boys and 34 girls) were taught using a constructivist-informed, technology-rich teaching methodology (involving interactive whiteboards and ActiveStudio software) and the other two (25 boys and 33 girls) were taught using traditional teaching methodologies. Student achievement was evaluated using a chemistry achievement test consisting of sections on multiple choice, short answers and essay type questions. The mean gain in achievement score for the constructivist group compared to the traditional group was statistically significantly higher on the total test as well as on the sections of the test. Moreover, there were no gender-differences in the mean achievement score for the constructivist group, whereas such differences in the traditional group were statistically significant. These results suggest that a constructivist-informed, technology-rich teaching approach compared to a traditional teaching approach was more effective in improving the achievement of students as well as in minimising the gender differences in academic achievement. It is therefore recommended that teachers use this teaching technique to help their students learn chemistry better and achieve higher grades.

Introduction

According to constructivism, learning occurs when students actively construct new knowledge or concepts based on their prior knowledge or experience (see, for example, Bodner, 1986). A constructivist approach to learning involves the use of active learning strategies such as group work and discussion that allows the individuals to explore beyond the information given to them. The teacher and students are engaged in active dialogue where the main task of the teacher is to present information to be learnt to match the students' current state of understanding supported by their prior knowledge.

If the students are active then they are somehow constructing knowledge. Passive students are also constructing knowledge. However, the rate of construction is very slow, thus making it a less effective mode of knowledge construction.

In general there are two broad interpretations of constructivism: Individual Constructivism associated with Piaget, and Social Constructivism associated with Vygotsky (Ismat, 1998). In Individual Constructivism, emphasis is given to cognitive development, where the purpose of education is to educate a child according to their interests and needs. The students come to the classroom with ideas and beliefs that need to be modified by the teacher. Knowledge is constructed by devising appropriate tasks and questions that explore a student's understanding (Wang, 2003). Social Constructivism emphasised the role of language and culture in cognitive development. Language and culture are tools that can control and change a student's different forms of behaviours and cognition (Wang, 2003). As a result, the human cognitive structure is essentially socially constructed. Knowledge is not simply constructed by individual learners but is also co-constructed through social interaction (Simpson, 2002).

If we walk into many classrooms today and look at the way students are taught, we might see three different views of common classroom practices. Firstly, the teacher is pouring knowledge into the students' heads and the students might appear to be engaged in the act of soaking up everything the teacher says. Secondly, the teacher is trying to pour knowledge into the students' heads, but the knowledge just spills out. Finally, the teacher is trying to pour knowledge into the students' heads but the students do not always understand what the teacher is saying even though they are trying their best to retain the knowledge but lack the skill to do so (Leonard, Gerace and Dufresne, 1999).

All three views are characteristic of traditional classrooms, which are derived from the philosophy of objectivism. Communication occurs only in one direction where the teacher is primarily active in transmitting knowledge while the students are passively acquiring the knowledge being offered. Having made the assumption that students would understand everything, the progress of the students is regularly examined or tested using tests that the teacher designs and, most of the time, students are left to a system of memorisation. Therefore, assigning problems is not usually a good measure of conceptual understanding (Hoehnke, Koch and Lutz, 2003). In contrast, a constructivist view of learning is derived from experience, social interaction, and communication. Learning occurs through a process in which students are active constructors of knowledge (Li, 2001). The knowledge is constructed through observation, reflection and interaction with the surrounding environment such as their peers, teachers or technology. The teacher no longer acts as the sole transmitter of knowledge but as a facilitator offering suggestions to the solution of a given task. The concept that knowledge is transferred from the head of the teacher to the head of the student is abandoned in constructivism.

Lord, Travis, Magill and King (2005) compared the effects of traditional (teacher-centred) and constructivist (student-centred) learning styles on students' interest and performance. They reported that students in the traditional style classrooms were taught in a lecture format and the concepts were explained before laboratory work. In the other class, students were asked to discuss relationships and concepts with team members and make a presentation on it before laboratory work began. Tests were carried out ev-

ery week to determine any difference between the two groups. They found that student-centred learning not only helped students have a higher average grade on their weekly test but also showed more student participation, a high level of satisfaction, willingness to answer or ask questions, and a better interest towards science when compared to students in the traditional or teacher-centred environment.

Similar results have been reported in another study (Santmire, Giraud and Grosskopf, 1999). They reported that students in a middle school environment who were involved in a social-constructivist approach to education achieved higher gains in standardised test scores than those students who were involved in the more classroom-based ‘abstract’ instruction. The teachers who participated in the social-constructivist approach to education had designed service-learning projects in which the teachers and students were involved with the community. Student involvement in the projects during the school day enhanced their performance.

The influence of active participation on student achievement was also studied by Pratton and Hales (1986). Selected teachers were trained in using the techniques of active participation and identified active participation used by other teachers. They found that the mean achievement of the class taught with active participation is greater than the class taught without active participation. Active participation has made a difference in the degree of student learning and was said to be an efficient teaching method as the students spent more time in doing activities that required thinking, responding and verifying what they know.

Technology can now be used as a tool in the science laboratory by students of all ages (Krajcik and Layman, 1992). Devices such as data loggers, which can measure things in the real world such as temperature and light intensity, can now be connected to the computer. Technology allows students and teachers to acquire new information about the world in a way that is exciting and can make a major contribution to the conceptual scientific development of the students. The ability of the technologies to transform these data into a graph in real-time as the experiment progresses is a critical contribution to conceptual development.

The impact of learning, with effective ICT practice, on student motivation was studied by Passey, Rogers, Machell and McHugh (2003). They found out that ICT: (i) has motivated students in their commitment to learn and participate in learning activities, (ii) has improved students’ quality of work and has given them the confidence to perform enhanced learning tasks, (iii) has allowed students to learn independently, which has enabled more work to be completed, and (iv) has enhanced attainment due to the reinforcement and practice that ICT has afforded.

Contradictory to the above studies, Ye (2002) reported no effect on the usage of technology and instructional material on science achievement of 15 667 tenth grade students. In their study, each student responded to a survey designed by the National Center for Education Statistics (NCES), and multiple linear regression was used to get the effects of teachers’ usage of instructional materials on student achievement. From the analysis, teachers’ usage of instructional materials did not show a significant correlation with student achievement. Jabaidah (2002) found that even though the use of ICT with practical manipulative activities is effective in enhancing teaching, levels of achievement were found to be low. Mohd Zamri (2004) used a PowerPoint program as an ICT tool to present lesson content, which involved animated pictures, annotations,

video clips, and online websites. He reported no significant differences in the achievement of students learning with and without the use of ICT despite both authors being optimistic that when teachers used ICT and instructional materials more effectively, student achievement would be improved significantly.

The above studies suggest that the use of technology in the classroom can improve students' learning. However, technology itself will not contribute to students' performance unless teachers create a learning environment that stimulates students to be active, co-operative and to take more responsibility in the learning process (Smeets and Mooij, 2001). Establishing a pupil-centred technology learning environment requires a shift from common practice in classrooms to innovative lessons in which technology use is integrated into pupil-centred learning environments. In other words, the technology-rich learning environment should stimulate active learning, discovery learning, and higher-order thinking skills.

A study was conducted by Shute and Gawlick-Grendell (1994) to determine the degree to which computerised instruction (Stat-Lady) contributes to learning when compared to traditional paper and pencil instructions using workbooks. An important feature of Stat-Lady was that students were encouraged to interact actively in the learning process using graphics, animations, speech, and sound effects. Students enjoyed themselves more when learning using Stat-Lady and possessed slightly greater procedural skill since the environment required them to be actively engaged in the learning process. Due to the more appealing environment, with colourful displays and sound effects, these students also performed better than students learning from the workbook.

In another approach, which was studied by Gerace, Dufresne and Leonard (1999), active learning was incorporated into large classes that made use of a new technology named Classtalk, which facilitated instructions. The technology allowed teachers to create a classroom environment that was based on constructivist epistemology that is lively and rich, where co-operative learning, discussions and interactive classroom instruction was carried out without losing control of the class. Communication in terms of student and teacher interactions were greatly enhanced which affected both learning and instruction. Students realised that not only did their understanding and problem solving skills improve, their attitudes and motivation toward science also improved.

Technologies such as overhead projectors, television, slide projectors, and other related devices have been adapted, integrated into the educational process, and have been part of teaching and learning. However, in the last decade, there has been a tremendous growth of newer electronic technologies, namely personal computers, compact discs, the Internet and even interactive whiteboards, which in some way have influenced the teacher's role in teaching and created new interest on how to use them for teaching and learning.

In a traditional classroom learning environment, the chalkboard or the whiteboard is the medium through which teachers convey their lessons. The newest technology, which is available for teachers to enhance the effectiveness of their lessons, is the interactive whiteboard. It is a large, touch-sensitive board that is connected to a digital projector and a computer. The projector displays an image from the screen of the computer to the whiteboard. When the three devices run simultaneously, the computer can be controlled from the board using an electronic pen. The interactive whiteboard enables teachers and students to write directly on the board that permits highlighting,

labelling and erasing of content, and the ACTIVstudio software consists of flipcharts that simulate traditional chalkboard presentation, but that are embedded with storage, retrieval and integration of multimedia capabilities. In contrast to the traditional chalkboard, the interactive whiteboard allows interactions to be carried out not only with any application on the interactive whiteboard itself but also with students and their teachers (Cuthell, 2005).

Due to the interactivity of the whiteboard, it has benefits for teaching and learning. It enables teachers to integrate ICT into their lessons while teaching from the front of the class and saving what is on the board to reduce repetitive lessons and make revision easy. The interactive whiteboard enhances students' enjoyment and motivation in their lessons as it allows greater opportunities for participation. The need for note taking can be reduced as the content that appears on the whiteboard can be saved and printed as handouts. There has been little research done on the impact of the interactive whiteboard on teaching and learning, which might be due to it being a new technology.

Dantzker (2002) conducted a survey on 609 secondary school students from South Texas Community College to find out their perceptions of the use and educational value of seven types of educational technology, the interactive whiteboard being one such technology. The students were asked to rate how much the use of the technologies in each class had helped them learn. The result showed that 72 per cent of the students found the use of the interactive whiteboard had helped them a lot in their learning. The students also felt the use of the interactive whiteboard to be helpful when used with other types of technology except the television.

Kennewell and Beauchamp (2003) investigated the impact of the interactive whiteboard technology on students' activities and learning. In a school where the head teacher expected the use of the interactive whiteboard, key features showed which were observed in the classroom. The use of the interactive whiteboard was effective in gaining and keeping students' attention. Teachers felt the large visual display, with a variety of representation was the contributing factor. Participation from students was increased as they were allowed to approach the board and interact with the materials. The interactive whiteboard has allowed teachers to face the students all the time and to remain engaged with students' thinking.

The results of another study (Beeland, 2002) indicated that the use of the interactive whiteboards in the classroom does lead to increased student engagement. The teacher presented lessons using an interactive whiteboard to 197 students in ten middle schools. Instructions that were delivered using the whiteboard were interesting, relevant, appealing and involving. The manner or method in which the teacher used the whiteboard also had affected the degree to which the students were engaged. The effective use of the whiteboard was highly correlated with the type of media that was used.

The above discussion suggests that when interactive technology and a constructivist learning environment are fused together in a classroom situation, student achievements and attitudes can be improved. Since this technology is new, little or no research has been done in this area, therefore it is important to investigate this hypothesis. If such an hypothesis is tested positive, then it means that this approach can be used to improve student achievement. An improvement in student achievement scores may indirectly encourage the students to pursue their studies further in science-related fields.

It was therefore decided to teach a group of students using the constructivist teaching approach with the aid of technology and the other group using a traditional teaching approach to compare the achievements of the students and to find out whether there are differences in achievement. Here males and females were considered separately.

Aims

The purpose of this study was to compare the learning outcomes of students in a constructivist-informed, technology-rich teaching approach and a traditional teaching approach. The present study attempted to answer the following research questions: (i) how does student achievement compare in the constructivist-informed, technology-rich and traditional learning environment, and (ii) how do the effects of gender on student achievement compare in constructivist-informed, technology-rich and traditional learning environments?

Methodology

The participants in the study were Form V combined science students in four classes. Two of the four classes were taught with the traditional teaching approach and were called the traditional approach group (TAG). The other two classes were taught with the constructivist teaching approach with the aid of technology and were called the constructivist approach group (CAG). The traditional approach group had 58 students (25 boys and 33 girls) while the constructivist approach group had 57 students (23 boys and 34 girls).

The intervention using both the traditional and constructivist-informed, technology-rich approaches was conducted in three stages. In the first stage, both groups were administered the achievement test as a pre-test. The achievement test was conducted before the start of the intervention. It consisted of eight multiple-choice questions, seven short-answer-type questions and one descriptive-type question. For each multiple-choice question, the students were required to select one correct answer out of four given response options. They were also required to write the logic for selecting their responses in the multiple-choice section so that more information could be obtained on student knowledge. The short-answer-type questions consisted of higher cognitive level questions. These questions required the students to analyse graphs, tables and diagrams to answer questions that came with it. The descriptive-type question was an essay-type question that required the students to write an essay on a particular topic of organic chemistry. In stage two, six lessons on organic chemistry were conducted over a period of six weeks (one lesson per week). Each lesson conducted was a 60-minute lesson. The topics covered were fuels, name of compounds, homologous series, alkanes, alkenes and alcohols. The teacher and students in the constructivist approach group had utilised the interactive whiteboard and the software ActiveStudio, while the students in the traditional approach group did their lessons without the use of the technologies. In stage three, the traditional and the constructivist approach groups were administered the achievement test as a post-test.

Lessons in the constructivist approach group were conducted in the ICT room where the interactive whiteboard and the ActiveStudio software were utilised in a con-

structivist teaching and learning environment. ActiveStudio software was used both on the interactive whiteboard as well as on the students' computers. This software was used to develop teaching materials on the topic of organic chemistry. The teaching material was designed to promote the constructivist teaching and learning environment and active participation of the students through collaborative work. The students were given a set of worksheets and they were required to complete these collaboratively by making use of the developed teaching material on their computer. The teaching material engaged the CAG students extensively and they were on task for most of their time they spent on problem solving. Before the end of every lesson, the CAG students were instructed to summarise the topic that they had learnt in the lesson. Thereafter, the CAG students were asked to go over their summaries as well as their class notes to see what information they had missed out in their descriptions. They then shared their work with their peers to reorganise their constructed knowledge in order to minimise differences in the conceptions of different students. The TAG students were taught according to the teacher's own style of teaching organic chemistry and all the lessons were conducted in the chemistry laboratory, presented in a traditional way with the aid of the teacher's prepared transparencies and whiteboard.

Results and discussions

Table 1 shows the paired sample t-test analysis data for the pre- and post-intervention tests scores for the CAG and TAG students.

Group	N	Mean±SD (%)		Pre- vs Post-		
		Pre-test	Post-test	t-value	p-value	ES
TAG	42	30.82±2.73	56.29±7.45	-10.71^*	0.00	2.16
CAG	46	23.77±3.65	55.88±7.20	-14.94^*	0.00	2.68

$p \leq 0.05$; ES: Effect Size; TAG: Traditional Approach Group;
CAG: Constructivist Approach Group.

Table 1: Mean pre- and post-intervention achievement test scores for TAG and CAG students.

The t-test analysis results show that there were statistically significant increments in mean scores from the pre- to the post-test for the students in both groups, with large effect sizes of 2.16 and 2.68 respectively. The students in both groups achieved higher post-test mean scores than pre-test mean scores. These results suggest that both teaching methods helped the students to improve their learning. The effect size of 2.68 as compared to 2.16 for the CAG students suggest that the improvement in the achievement scores from the pre- to the post-intervention was greater for the CAG students. Similar results are reported by Talib, Matthews and Secombe (2005). According to them, both teaching methods produced higher post-test than pre-test mean score. In the present study the post-intervention mean achievement scores for both the groups were above 50 per cent suggesting the score to be in the pass range. Hence, the gains in achievement scores for both the groups were of educational importance. These results are further supported by minimum (TAG = 28.13%, CAG = 27.08%) and maximum

(TAG = 83.33%, CAG = 86.46%) marks for both groups. A mark of 80 per cent or above corresponds to a grade of A in the Bruneian educational system. The standard deviation values also suggest that some students achieved mean test marks more than 60 per cent, which is equivalent to a pass with credit in the local examination system.

Sections	Group	Mean±SD(%)			TAG vs CAG	
		Pre-	Post-	Gain	p	ES
Total	TAG	29.40±3.40	56.29±7.45	25.50±7.41	0.04*	0.91
	CAG	23.77±3.65	55.88±7.20	32.08±6.99		
MCQ without logic	TAG	48.38±1.39	81.88±1.53	32.50±2.06	0.01*	7.40
	CAG	40.50±1.55	87.25±1.02	46.75±1.76		
MCQ with logic	TAG	18.71±2.03	53.58±5.12	34.63±5.86	0.56	–
	CAG	15.75±2.14	53.25±5.02	37.50±5.12		
Short Answer	TAG	39.46±2.49	53.46±2.46	11.50±2.06	0.00*	2.61
	CAG	31.79±2.27	49.33±2.29	17.54±2.48		
Essay	TAG	3.20±0.37	33.40±1.24	29.60±1.21	0.02*	9.96
	CAG	0.00±0.00	44.00±1.61	44.00±1.61		

$p \leq 0.05$; p and ES values for gain scores comparison only; TAG: Traditional Approach Group ($N = 42$); CAG: Constructivist Approach Group ($N = 46$).

Table 2: Mean pre-test, post-test and gain scores for TAG and CAG students.

Since both teaching methods helped students to improve their learning, it was felt appropriate to look at how the two teaching methods contributed to the extent of gain in achievement scores. This was achieved by computing the mean gain in achievement scores for each of the TAG and CAG students by subtracting the pre-test scores from the post-test scores. The mean gain scores were then compared using One-Way ANOVA. Since the achievement test consisted of multiple-choice questions (MCQ), short answer and essay questions, it was decided to compare the nett gain scores for these test components too. The MCQ usually involved selecting an answer from given choices, but in this study, the students were asked to describe the logic for selecting a specific MCQ response. Therefore, the MCQ component scores are reported in two sections, one without considering a student's logic and the other which considers a student's logic. Hence, a students mean achievement scores on the four sections are reported along with the total test mean score in Table 2. The table shows the ANOVA analysis results of the mean gain in the achievement test scores and in the four test components for the TAG and CAG students.

A comparison of the total test gain scores revealed a statistically significantly higher mean gain for the CAG students when compared to the TAG students, and the difference produced a large effect size of 0.91. The mean gain scores on the test components for the CAG students were also higher when compared to the TAG students. However, the CAG students' mean gain scores on the test components were statistically significantly higher only for the MCQ without logic, short answer and essay sections than the TAG students. Large effect sizes of 7.40, 2.61 and 9.96 were observed for the differences in mean gains for these three sections respectively. These results suggest that although both teaching methods can produce large gains in achievement, the use of

the constructivist teaching approach aided with the use of technology produced larger gains in achievements when compared to the traditional teaching approach.

Table 3 shows the One-Way ANOVA analysis results for the mean gain scores on the achievement test and the test components for the male and female TAG students. The table shows that both the male and female TAG students achieved a higher mean score on the post-achievement test than on the pre-achievement test. The difference in mean gain scores for male and female students was statistically significantly different (p = 0.00, ES = 2.49). The female TAG students recorded higher mean gain score on the achievement test than the male TAG students. The table also shows that both the male and female students showed improvements in the post-test mean scores on the sections of the achievement test, however the female students had higher mean gain scores than the male students. Statistically significant differences in mean gain scores were observed for the MCQ with logic, MCQ without logic, as well as for the essay sections of the achievement test, with high effect size values of 14.30, 4.98 and 15.72 respectively. These results indicate that the use of the traditional teaching approach appears to favour female students in learning organic chemistry, thus creating gender differences.

Sections	Gender	Mean±SD(%)			Male vs Female	
		Pre-	Post-	Gain	p	ES
Total	Male	28.94±3.85	47.92±7.66	17.04±7.34	0.00*	2.49
	Female	29.71±3.13	63.92±5.09	33.19±5.32		
MCQ without logic	Male	50.63±1.53	71.88±1.74	18.75±1.88	0.00*	14.30
	Female	47.00±1.30	90.88±0.83	44.88±1.71		
MCQ with logic	Male	19.67±2.05	42.08±5.19	21.25±5.54	0.00*	4.98
	Female	18.04±2.03	64.00±3.61	46.79±4.52		
Short answer	Male	37.58±2.78	51.46±2.71	11.17±1.88	0.80	–
	Female	40.71±2.28	55.29±2.18	11.83±2.26		
Essay	Male	3.60±0.39	24.00±1.11	20.00±1.12	0.01*	15.72
	Female	3.00±0.36	41.80±1.23	38.20±1.15		

$p \leq 0.05$; $N = 22$ (for male); $N = 24$ (for female); p and ES values for gain scores comparison only.

Table 3: Mean pre-test, post-test and gain scores for male and female TAG students.

Table 4 shows the One-Way ANOVA comparison results of the mean gain scores on the achievement test and its four components for the male and female students in the constructivist approach group. The table shows that both the male and female CAG students achieved a higher mean score on their post-achievement test than on the pre-achievement test. However, the mean gain scores for both genders were statistically non-significantly different. The male and female CAG students also achieved higher post-test mean scores than pre-test mean scores on the sections of the achievement test. These differences in mean gain scores were also statistically non-significantly different. Unlike the traditional approach to teaching and learning, the constructivist approach did not create any discernible difference between the genders. It is believed that this teaching technique created an environment that is equally favourable to both male and

female students. In this learning environment, most of the time, both the male and female CAG students tend to work more co-operatively with their peers and teacher to complete the tasks assigned to them. However, most of the TAG students' interactions were limited to inter-gender interactions only (female to female; male to male). Kumar and Helgeson (2000) in another study reported that the use of Hyper Equation software on Macintosh computers to solve stoichiometric chemistry problems helped to narrow down the gender gaps in achievements.

Sections	Gender	Mean±SD(%)		Male vs Female	
		Pre-	Post-	Gain	p-value
Total	Male	22.88±2.94	55.77±6.97	32.92±7.47	0.72
	Female	24.60±4.22	55.94±7.55	31.33±6.67	
MCQ without logic	Male	36.88±1.50	84.63±1.19	47.75±2.02	0.77
	Female	43.75±1.59	89.63±0.82	45.88±1.52	
MCQ with logic	Male	13.25±1.76	51.88±5.34	38.63±5.46	0.73
	Female	18.04±2.33	54.50±4.80	36.46±4.89	
Short Answer	Male	32.50±1.94	50.58±2.24	18.08±2.55	0.73
	Female	31.17±2.57	48.17±2.35	17.00±2.47	
Essay	Male	0.00±0.00	43.60±1.62	43.60±1.62	0.96
	Female	0.00±0.00	44.20±1.64	44.20±1.64	

p values for gain scores comparison only; $N = 22$ (for male); $N = 24$ (for female).

Table 4: Mean pre-test, post-test and gain scores for male and female CAG students.

Summary, conclusions and implications

This study reports that both the traditional teaching approach, and the constructivist teaching approach with the aid of technology were effective in improving the achievement of the students in an organic chemistry related topic. However, when the mean gain in the achievement scores were compared, the constructivist teaching approach managed to produce a statistically significant higher mean gain score than the traditional approach group. The mean gain scores on the components of the achievement test were also observed to be statistically significantly higher for the CAG than for the TAG students. The CAG students had statistically significant higher mean gain scores on the MCQ without logic, short answer and essay components of the achievement test than the TAG students. When the performance of male and female students in both groups of students were compared on the achievement test and its components, the traditional teaching approach appears to encourage more gender differences than the constructivist teaching approach. The female TAG students have statistically significant higher mean gain scores on the achievement test and on the MCQ without logic, MCQ with logic, and essay components of the achievement test when compared to the male TAG students. These differences in the mean gain score between the female and male students were not observed in the constructivist approach group. It is believed that the inter- and intra-gender interaction in the constructivist approach group helped the CAG students. These interactions were very much more limited in the traditional

approach group.

The present study is based on the constructivist theory of learning, where technology (ActiveBoard) is used as a tool to help students work collaboratively and actively acquire, construct, and organise knowledge. Results of the study have shown that the use of technology in a constructivist teaching and learning environment significantly improved the students' achievement scores on a chemistry-related topic. The mean gains in achievements for the CAG students were statistically significantly larger when compared to the TAG students. Thus, if teachers intend to integrate technology in the curriculum as a tool for teaching and learning, special attention needs to be given to the classroom environment created. The technology-rich learning environment should allow students to learn collaboratively in order to acquire, construct and reorganise their own knowledge. Today, the role of the teacher has not only shifted towards being a facilitator and student motivator but also to structure the learning environment so that the students are able to take ownership of their own learning (Theroux, 2004).

One of the challenges of using technology in education is achieving gender equity in the achievements of students as reported in the study by Owens and Waxman (1998), where inequities related to the use of technology by students have an effect on academic outcomes. However, in this study the constructivist teaching approach with the aid of technology did not create gender difference in achievements, unlike the traditional teaching approach. The CAG students were arranged and seated differently to the traditional classroom, allowing more students inter- and intra-gender interactions and collaborative work. Thus, it can be argued that allowing the male and female students, grouped together under teacher supervision, to create a learning environment that allows them to work collaboratively in constructing their knowledge would eliminate gender differences in achievements that have emerged in the traditional teaching approach. For this reason it is also recommended that teachers use this teaching approach to achieve gender equity in their classes to help more students achieve better grades in science subjects so that this will encourage them to pursue their studies further in science-related fields.

Science teachers can use the findings of this study to integrate the technology in their teaching. The previous studies have demonstrated that if technology is simply used as a means for displaying the information to the students, as in a PowerPoint presentation, student achievement does not improve. But, improvement has been observed in this study when technology is properly integrated in the curriculum. Teachers therefore should integrate technology with the latest teaching techniques in order to optimise the effectiveness of the teaching and learning process. The curriculum department can benefit from this research as it highlights the need to develop new curricula materials that can be taught using interactive whiteboard. This research highlights a need for teachers to be trained in learning techniques where constructivist teaching and the latest technology are integrated. Only teachers properly trained in this area can be effective. Therefore teacher training institutions are required to redefine their priorities in training teachers. This study suggests that interactive whiteboard can be used to improve student learning outcomes. It is therefore important that school administrations and the Ministry of Education should provide these facilities to schools. So far only one interactive whiteboard per school is available. There is a need for more of these facilities to be made available to schools. Moreover, more research in other subject areas

using the technique described in this study are also desirable.

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Blow a surprise and twenty-five other simple physics demonstrations

Seán M. Stewart[1] and Marinus P. Dirks[2]

[1]Core Mathematics, The Petroleum Institute, Abu Dhabi, United Arab Emirates
[2]Core Physics, The Petroleum Institute, Abu Dhabi, United Arab Emirates

Abstract

Physics attempts to reduce the complicated workings of nature into a few simple fundamental principles that have the widest applicability. And so it ought to be the case that the simplicity so sought after in understanding nature should extend to the way we teach physics, particularly at the introductory levels. In this paper a collection of simple, classroom-ready physics demonstrations are described. In all cases, the demonstrations have been chosen to show how the simplicity of nature, while often hidden, can be coaxed out into the open using only the simplest of equipment.

Introduction

The importance and use of carefully selected demonstration experiments in the teaching of physics should not be underestimated. It is often the case that many teachers of physics seldom employ demonstrations as an effective teaching tool in their own classes. This is surprising considering, as Ehrlich (1990) has pointed out, '…most of [our] colleagues love to watch a good demonstration' (p. xv). Nor is it any different with the students we teach. Not only do students find demonstrations fun and a welcome interlude from theory, they can, more importantly, help students to acquire basic familiarity with physical phenomena, something they often lack when they arrive in our classrooms. Moreover, demonstrations can be used to help clarify a particular physical principle (Stinner, 1994), overcome common misconceptions by challenging previously held, but incorrect, notions (Halloun and Hestenes, 1985), or show an interesting application of a physical principle (Sutton, 2003).

Continuing in a spirit similar to that used previously (see, Stewart, 2005a), we once more set out with renewed optimism and vigour to describe a completely new set of physics demonstration experiments which, on the one hand, remain simple and highlight how nature behaves without having to resort to obtrusive equipment and which, on the other hand, most will find either interesting, intriguing, or simply a little different. In doing so it is our intention to show demonstrations whose simplicity and convenience are sufficiently compelling to prompt those who tend not to use demonstrations

in their teaching as often as they could, to approach the use of simple demonstrations in their teaching with renewed interest.

Once more, all the selected demonstration experiments are taken from topics one typically finds in any standard course on general introductory physics, and are applicable to both upper secondary- and lower tertiary-level teachers of physics. In selecting the demonstrations to describe, each had to pass two essential criteria. Firstly, each should reveal the underlying physical principle in the simplest possible way. Secondly, each should not rely on otherwise strange and foreboding equipment for its demonstration. Often it is the case that the use of unfamiliar equipment tends to obscure in the minds of our students the physical principle one is trying to demonstrate in the first place and, accordingly, should be avoided wherever possible. Demonstrations of unanticipated, surprising, or counter-intuitive effects have also been sought. Not only are these fun to do but they also act as an invaluable teaching aid since not only are they able to promote critical thinking, but they invite students to challenge initially held notions about a particular concept. It is important to remember that many of our students come to us holding many alternative conceptions and lacking any real sense for physical intuition (see, for example, Knight, 2004).

Pedagogically, simple demonstration experiments provide students with an opportunity to gain basic familiarity with a range of physically important phenomena. Importantly, demonstrations can be used as predicating, observing, and explaining tasks rather than as a measuring task. Sadly, it is often the latter which tends to dominate the standard laboratory component of most introductory physics courses we teach and have been found to be not very effective in instilling in our students a deep sense of awareness for physical phenomena (Knight, 2004). In fact, Knight goes further when he writes that introductory physics teaching ought to be about understanding physical phenomena rather than about mathematics and other unnecessary abstractions. Thus the development of physical intuition is more easily understood if it is presented unencumbered in the form of a simple demonstration rather than the concept being burdened under a weight of abstruse mathematical abstraction.

A collection of additional simple physics demonstration experiments has been given previously by one of the authors (Stewart, 2005a). An excellent, though somewhat dated, review of the physics demonstration literature can be found in a resource letter by Davis and Eaton (1979). This resource letter covers the full gamut of demonstrations one can perform from the traditional lecture or classroom type demonstration to those which can be performed in other settings such as hallways, in the laboratory, at home, on large playing fields, and the like. A good and continued source of ideas for simple demonstrations remains the publications of the two professional bodies for teachers of physics in the UK and the US, namely *Physics Education* and *The Physics Teacher* respectively. Finally, for a poll of *Physics World* readers – a monthly publication for physicists by the Institute of Physics in the UK – to find the ten most beautiful experiments in physics, see Crease (2002). Surprisingly, a number of the top ten experiments identified come directly from topics taught at the introductory level. For additional comment in this regard, see either Parker (2002) or Carr (2005).

Nice and simple

The first six demonstrations are all very simple to perform. Simplicity to perform, however, can be deceptive. Each require careful thought in order to be explained since the results of some turn out to be quite subtle.

Finger friction and the sliding ruler

Take a uniform metre-stick and place both index fingers underneath the ruler at either end. Slowly slide your fingers together until they meet. Your fingers will always meet at a position where the *centre of mass* of the object is located, which in the case of a uniform metre-stick will be at its geometric centre. Attaching a small mass to one end of the metre-stick and sliding one's index fingers results in them meeting at a position closer to the end where the mass is supported; the centre of mass of the ruler plus the additional end mass. The centre of mass of an object is the place where one can balance the object using a single finger only. When one starts to slide one's index fingers, one finger will be slightly closer to the centre of mass than the other. Accordingly, one finger supports a slightly larger weight force. As the size of the static frictional force on one's finger is related to the size of the contact, and hence weight force between the ruler and one's finger, the finger supporting the least weight will begin to slid first. As this finger slides it moves closer to the centre of mass of the object and in doing so leads to it supporting a larger weight force of the ruler. However, as the coefficient of sliding friction μ_k is less than the corresponding coefficient of static friction μ_s, it is possible for the finger which is sliding to move closer to the centre of mass under an increasing weight force. Eventually, however, the size of the frictional force on the sliding finger becomes greater than the stationary finger and leads to a swapping over where the stationary finger now begins to slide while the sliding finger stops. This process continues to alternate until both fingers meet at the position under the centre of mass. See Doherty, Rathjen and the Exploratorium Teacher Institute (1996, p. 29), or Ehrlich (1990, D.9, pp 49–50) for a more detailed mathematical analysis.

Three-corner reflector

Place three square plane mirrors so that they are mutually perpendicular to each other like the internal corner of a cube. Any incidental ray of light which is reflected off one, two or three mirrors in such an arrangement will be reflected back towards the source along a path parallel to the incidental ray no matter what the initial angle of incident is. Thus an image of an object can always be seen in a so-called *three-corner-reflector* regardless of the angle from which the reflector is viewed. This principle is the basis behind many reflectors, such as those found on bicycles or on roadways, which have tiny three-corner reflectors embedded into the reflecting surface. Perhaps the most famous of all three-corner reflectors is the array left behind on the Moon by astronauts in 1969, which has been used to measure the distance between the Earth and Moon to an accuracy of a few centimetres (Tipler and Mosca, 2004).

Spinning eggs

How do you tell the difference between a hard-boiled egg and a raw egg? Why, one uses inertia of course. Take a hard-boiled egg and another which is raw and spin them both on a smooth flat tabletop. Gently halt the spinning of each egg by quickly pressing your index finger on top of each egg and releasing. After releasing your finger, one egg will

remain stationary while the other will slowly, as if by magic, start to spin again. The egg that starts to spin again is raw while the one that remains stationary is hard-boiled. Since the liquid egg-white and yoke inside the raw egg is only loosely attached to its outer shell, when the outer solid shell suddenly stops spinning, inertia ensures that the somewhat detached liquid egg-white and yoke inside the shell continues to spin. Once the shell is released, the spinning egg-white and yoke inside the shell slowly, due to the effects of friction, causes the outer shell to start rotating again. In the case of the hard-boiled egg, since the shell and solid egg-white and yoke inside constitute one solid unit, once the outer spinning shell is brought to rest so is the inner solid egg-white and yoke and all rotation within the system disappears so that on release, the hard-boiled egg is unable to start spinning again. For an alternative approach to discovering an egg's inner secret, see Press (1998, p. 171).

The Cartesian diver

The Cartesian diver is a very old but simple experiment demonstrating the effects of buoyancy on an object in a liquid. The diver takes its name from its inventor, the French mathematician and philosopher René Descartes (1596–1650), who invented it in the early 1600s (Provenzo and Provenzo, 1989), and has continued to remain popular ever since. An upturned pen lid or folded-over piece of drinking straw containing a pocket of trapped air (the 'diver') is weighed down with some Blu-tack at the open end so that it barely floats on the surface of a large plastic bottle which is completely filled with water. The cross-section of the bottle should be roughly circular. With the lid of the plastic bottle firmly screwed on, the sides of the bottle are squeezed and the diver is observed to slowly sink to the bottom of the bottle. On releasing the sides of the bottle the diver floats back up to the surface. According to Archimedes principle, an object which is either floating or submerged in water is acted on by a buoyant force equal to the weight of the volume of water displaced by the object. Initially, since the weight of the amount of displaced water is equal to the weight of the diver, it floats. Squeezing the sides of the bottle increases the pressure everywhere inside the bottle. Such an increase in pressure causes the size of the air pocket inside the diver to decrease as it becomes compressed. The diver therefore displaces less water leading to a decrease in its buoyancy that finally causes it to sink. On releasing the sides of the bottle from being squeezed, the pressure decreases everywhere inside the bottle, and in turn causes the trapped air pocket inside the diver to expand once more, increasing the amount of water the diver is able to displace, thereby causing an increase in its buoyancy which leads to it rising to the surface again. For slight variations on a theme to the Cartesian diver, see Ehrlich (1990) or Doherty, Rathjen and The Exploratorium Teacher Institute (1996). An interesting two-liquid Cartesian diver has been described by Planinšič, Kos and Jerman (2004).

Vortex connector

Fill one large plastic bottle three-quarters full with water and connect it to an identical bottle, which is empty, via their openings using an adapter. Invert the co-joined bottles and watch as the water from the top bottle slowly drains, due to gravity, into the bottom bottle. Here the drainage is painfully slow since, as it drains, the volume of air is reduced and leads to an increase in the air pressure in the bottom bottle while in the top bottle the volume of air increases and leads to a corresponding decrease in

air pressure. When the air pressure difference between the two bottles becomes large enough, it causes air from the lower bottle to bubble up through the water into the upper bottle. This is the painfully slow and all too familiar ‘glugging’ observed in upturned bottles being emptied in this way. So is there not a more effective way to quickly drain the upper bottle of its water? One needs to allow the air from the lower bottle to flow more easily into the upper bottle so as to avoid having to wait until a sufficient pressure difference in the air between the two bottles has built up. This is achieved by spinning the upper bottle filled with water so that a vortex forms. Once formed, the bottles no longer need to be spun. Gravity ensures that the water in the upper bottle is pulled down into the lower bottle. Due to the relatively small amounts of friction, the conservation of angular momentum ensures that the water continues to spin, and hence the vortex in the water persists, while the hole in the vortex at the opening between the two bottles allows the air in both bottles to equilibrate quickly and easily as the water rapidly drains. See Doherty, Rathjen and the Exploratorium Teacher Institute (1996, p. 98).

Static surface charge

Charges in a conductor distribute themselves in such a way that the excess charge resides on the outer surface of the conductor. The movement of excess charge to the outer surface of a conductor can be shown using a surprisingly simple demonstration. Consider a rectangular piece of wire mesh of approximate dimensions 20 cm high by 80 cm long. Position the wire mesh in the vertical plane by attaching three insulated stands to its base at either end and in the middle. To the mesh on either side attach a number of evenly-spaced, narrow strips of aluminium foil which hang vertically and should deflect easily upon the mesh becoming charged. The aluminium strips therefore behave like the leaves of an electroscope and are used to detect for the presence of static charge. The mesh now needs to be given a large excess charge. This is most easily achieved by connecting the dome of a Van de Graaff generator to the metal mesh using a wire, since the Van de Graaff generator is nothing more than a giant producer of static charge by friction. On charging, all aluminium strips on either side of the mesh will be observed to deflect away from the surface of the mesh by equal amounts. Now, if the two ends of the mesh are gradually turned inwards towards each other to form a closed loop, all the inner strips will be observed to collapse while the outer strips deflect even further. Such an observation indicates that, as expected, the excess surface charge of the conductor moves to its outer surface once the wire mesh is formed into a cylindrical loop. Changes in the shape of the surface, by making the mesh sharper or more pointed at places, result in the strips deflecting more and shows that the charge density at such places must be higher compared to those where the surface curvature is lower. This demonstration was inspired by Gluck (2004).

Blow a surprise

Many simple experiments on fluid flow that demonstrate Bernoulli’s principle can be performed. Bernoulli’s principle, discovered by Daniel Bernoulli in the mid-eighteenth century, states that when the speed of flow of a fluid increases, the corresponding internal pressure within the fluid decreases and is a consequence of the conservation of energy.

Blow a surprise using Bernoulli's principle: Part I

Roll a small piece of paper into a tight ball and place it just inside the neck of a clear glass bottle. Now blow as hard as you can into the neck of the bottle. Instead of the paper ball being blown further down into the bottle, you have instead blown yourself a surprise as it shoots straight back out of the neck of the bottle. Such behaviour is the result of Bernoulli's principle. Blowing into the neck of the bottle results in a decrease in pressure as the fast moving air causes a pressure difference between the air inside the bottle, where there is little to no air flow, and the air moving along the neck of the bottle. This pressure difference causes the paper ball to be pushed into a region of lower pressure, which just happens to be found at the opening of the bottle!

Blow a surprise using Bernoulli's principle: Part II

Blow into an inverted, transparent funnel which has a ping-pong ball initially held at the funnel's opening. Provided one can blow sufficiently hard, the fast-moving air exiting from the neck of the funnel and moving over the sides of the ping-pong ball causes a drop in pressure there in accordance with Bernoulli's principle while in the region directly beneath the ping-pong ball, the air is not moving and remains at normal atmospheric pressure. Thus, the difference in pressure between the top and bottom of the ping-pong ball leads to an upward lift force on the ball which in magnitude is (hopefully) sufficient to balance the weight force of the ball due to gravity. Before performing this demonstration most students expect that the ping-pong ball will be blown out of the funnel by the push of the moving air column. See Ehrlich (1990, H.11, p. 105).

Surface tension of water

The surface of water and other liquids behaves like an elastic membrane under tension. *Surface tension* therefore refers to the apparent 'skin' at the surface of a liquid. Here attractive intermolecular forces between neighbouring molecules are exerted on the molecules in the liquid. Within the liquid, since the intermolecular forces on all molecules are exerted equally in all directions, no nett force acts on the liquid molecules beneath the surface. At the surface of the liquid, however, the attractive intermolecular forces between neighbouring molecules only act sidewards and downwards. Thus, molecules at the surface are pulled downwards into the volume of the liquid due to the unbalanced force which acts on the molecules at the surface and leads to the surface behaving as if it were a tightened elastic membrane. Many simple and interesting experiments involving the surface tension of a liquid can be readily performed.

Thread a circle

Knot a piece of thread into a loop and carefully float it in a petri dish filled with water. The loop should float on top of the water as a result of surface tension. Dip the end of a matchstick which has already been dipped into some liquid detergent into the middle of the loop. On doing so, the irregularly-shaped loop will be drawn into the shape of a perfect circle. Here the detergent has the effect of reducing the attractive intermolecular forces between the water molecules at the surface. Thus, the surface tension of the water outside the loop is greater than the surface tension inside the loop, which now has a thin film of detergent over its surface. This difference in tension causes

the irregularly-shaped loop to be drawn out into a perfect circle.

Ravelling talcum powder magic
Sprinkle a thin layer of talcum powder over the surface of a petri dish filled with water. Once again the talcum powder will float on the surface of the water due to the surface tension of the liquid. Dip the end of a matchstick which has already been dipped into some liquid detergent near the side of the dish and watch all the talcum powder ravel up to the opposite side of the dish. Here again the detergent reduces the surface tension of the liquid at the point where it is dipped into the water and since the surface tension is greater at the opposite side, the contractive tendency of the surface pulls the surface and the layer of talcum powder with it due to the tension imbalance. See UNESCO (1962, F.10, p. 113).

Floating physics paradoxes

Fluid mechanics and its simpler sub-discipline of hydrostatics at the introductory level is often given little time and attention. Hydrostatics draws upon many of the general principles of mechanics, and as it contains many interesting paradoxes (see, for example, Fontana and Di Capua, 2005), these can potentially play a role in the teaching and understanding of many important ideas and concepts from mechanics. The next two demonstrations focus on the role paradoxes can play in the teaching of physics.

Displacement of a fluid: Part I
Place a small solid iron cylinder into the top end of a cut away plastic soft-drink bottle (the 'boat') so that it just floats in a beaker of water, and carefully mark the water level. Now ask students to predict if the water level will rise or fall if the iron cylinder is thrown overboard. The answer is not obvious and as Fontana and Di Capua (2005, p. 1024) point out, many famous physicists including the likes of George Gamow, Robert Oppenheimer and Robert Bloch have been reported to have answered incorrectly. The water level falls since the heavy iron cylinder is able to displace a greater volume of water in the boat than out. You may also compare the fall in water level if an equal volume cylinder of aluminium is used instead of iron. The floating boat containing the iron cylinder is able to displace a far greater volume of water compared to the floating boat containing the aluminium cylinder, since the density, and hence the weight, of the iron is much greater than that of the aluminium for equal cylinder sizes. The corresponding fall in water level is therefore greatest for iron compared to aluminium. See Press (1998, p. 142).

Displacement of a fluid: Part II
Again place a small solid iron cylinder into the top end of a cut away plastic soft-drink bottle (the 'boat') so that it just floats in a beaker of water, and carefully mark the water level. Next, remove the iron cylinder from its small boat and attach it to the underside of the boat using a small rubber band for example. If the boat is again immersed in the same beaker of water, will there be a change in the water level? It is interesting to pose such a question to students before performing the demonstration. Many have little to no idea if the water level will rise or fall. Since the total weight force of the boat–iron cylinder system remains unchanged, the water level when submerged in the beaker of water will therefore remain unchanged, as the same volume of water is displaced in

either case. It will be noticed, however, that the boat will float higher in the water when the iron cylinder is attached to its underside since in this situation the iron cylinder contributes to some of the displacement of the water. See Jargodzki and Potter (2001, p. 30).

Common misconceptions

It is well-known that learners of physics continue to hold notions of concepts which are often at odds with accepted scientific ones (see, for example, Hestenes, Wells and Swackhamer, 1992; Halloun and Hestenes, 1985). Such common misconceptions often persist in the learner despite physics teachers thinking they have taught their classes otherwise (McDermott, 1991). Simple demonstrations which are able to challenge a student's intuitive, or alternative, yet incorrect, conceptions is one way we as the teacher can help change such deeply held alternative conceptions towards more scientifically correct ones. The next three demonstrations try to challenge students' incorrectly held conceptions about some familiar physical principle or concept.

Three block drop

Ever since the time of Galileo, who showed by dropping balls of various mass from the campanile in Pisa that the descent time of an object in the absence of resistance is independent of its mass, physics students everywhere down the centuries have been told in innumerable classrooms that the fall time of an object dropped in a uniform gravitational field does not depend on the object's mass. This observation, however, still continues to come as a surprise to many students. Fortunately, the equal rate of descent for objects of different mass is very easy to demonstrate in the classroom. Take three identical wooden blocks and drop them simultaneously from an equal height of about two metres above ground level. Make sure each block is separated when dropped. Each of the three blocks should be observed to strike the ground at the same time. Next, drop the three blocks again from the same height except this time join two of the blocks together (we stick them together using small Velcro strips). The two joined blocks, which are now double the mass of the third block, all continue to strike the ground at the same time, hence confirming the fall time of an object is independent of its mass. A slight variation on this demonstration is to take three blocks, one large, one small, and one in the middle, and stack them together from largest at the bottom to smallest at the top. The block pyramid is then dropped from a vertical height, the higher the better. Since the acceleration of an object does not depend on its mass, the block pyramid falls to the ground as a single unit. It should be pointed out to students that this would not be the case if the misconception were true. Here, the larger block with the greater mass should have the greater acceleration compared to the other two blocks. Accordingly, each block should separate on descent with the larger block hitting the ground some time before the smallest one. For a number of other alternative ways to demonstrate why heavier objects do not fall faster than lighter objects, see Kibble (2001), Reynolds (2001), and Thomson (2001).

Tension in a string

Connect a block to a string which passes over a pulley at one end of a bench and tie the other end of the string to a spring balance. With the string balance held parallel to

the bench top, its reading while held at rest is used to measure the tension in the string. Now ask students what they expect to happen to the reading on the spring balance, and hence the tension in the string, if a second block of identical mass to the first were to be attached to the other end of the spring balance with a string and hung vertically over a second pulley at the other end of the bench. Most students expect the tension in the string to be twice as large, as it is being pulled 'twice as hard' (Knight, 2004). In fact, to the surprise of many students, the tension in the string remains unchanged as the two-block system remains at rest.

Half covered lens

Take a hand-sized double convex glass lens and use it to bring an image (of say a window and what lies outside) into focus on a screen. Now ask the class what will happen to this image if half of the lens is covered. Surprisingly, many students believe that only half of the previous image will be seen and this is a common misconception held by students (Goldberg and McDermott, 1987). Such a misconception is ascribed to students not fully understanding the ray model used for light, an abstract concept in itself, and how it relates to image formation. As is to be expected, the final image seen on the screen remains unchanged and is in no way diminished in size regardless of the area of the lens covered, provided, of course, that it is not completely covered. A complete and undiminished final image is still seen since, from the many light rays which emanate from the object, some still pass through the uncovered part of the lens, and are refracted as they pass through the lens by equal amounts as in the case of the uncovered lens, to form the same final image on a screen as before. Only the brightness of the final image is reduced since the amount of light passing through the covered lens to form the image is reduced.

Predictive challenges

Demonstrations where students are ask to predict the outcome beforehand can be used as a powerful pedagogical tool. After having performed the demonstration, incorrect student predications can help elicit common misconceptions.

Multiple images from two plane mirrors

An interesting exercise in plane mirror image formation is found by standing two plane mirrors side by side. Begin by placing two plane mirrors at right angles to one another and place a small object in front of the two mirrors. Ask the class how many images they expect to see. Of course one expects to see at least two images: one image of the object in the first plane mirror and another image of the object in the second mirror. Importantly, however, a third image is seen and is a reminder of the important property for all images formed by reflection (and refraction) that the image formed by one mirror serves as the object for the second mirror and vice versa. For the case of the two plane mirrors at right angles to one another, the image in the first mirror acts as an object for the second mirror and forms a final image while the image in the second mirror acts as the object for the first mirror and also forms a final image. The two final images formed in this way just happen to coincide with one another and thus this leads to three final images being observed. Other angles between the two mirrors lead to a different number of images being observed. It is an interesting exercise to have students

investigate the relation between the number of images formed N_i and the angle α between the two mirrors. The number of images formed is found to be equal to the largest integer part[1] of

$$N_i = \frac{360^\circ}{\alpha} - 1.$$

We therefore see that the number of images increases as the angle between the two plane mirrors decreases. For angles that divide 360 to produce integer divisors, we see that 2 images are seen when $\alpha = 120^\circ$, 3 when $\alpha = 90^\circ$, 4 when $\alpha = 72^\circ$, 5 when $\alpha = 60^\circ$, and so on. Notice also that the number of images seen tends to infinity as the angle between the mirrors tends to zero, the case when the two plane mirrors become parallel to one another. See either Ehrlich (1990, p. 178) or Doherty, Rathjen and the Exploratorium Teacher Institute (1995, p. 25) for further details.

Shortest finishing time

Two identical metal balls are allowed to roll along two tracks of equal length. The first track has one of its ends bent to form a small incline while the remainder of the track is horizontally straight (see below).

Track 1: 

The second track also has one of its ends bent to form an identical small incline as the first but is then followed by a second small incline, a second straight horizontal section before rising along an incline so that the two tracks finish at the same level (see below).

Track 2: 

If the balls are simultaneously released and allowed to roll along each track, students are asked to predict which ball will reach the end first. Since the initial and final track heights are the same, conservation of mechanical energy ensures that the speed of the balls at the end of each track will be the same. However, since the average speed of the ball rolling along the second track will be greater than that of the ball rolling along the first track, as the distance travelled by each ball is the same, the time taken to traverse the second track will be less than that of the first. This demonstration was inspired by a photograph of a similar demonstration which appears at the beginning of Chapter 3 of Hewitt's *Conceptual Physics* textbook (Hewitt, 2002, p. 39).

Spring block drop

Join two large blocks of wood together by a spring. Place the two blocks, attached to the spring, onto a tray with a rough surface so that when the spring is extended, both blocks are unable to move due the effects of friction. Now drop the tray from a height of about two metres and observes what happens. On dropping the tray, the two blocks will immediately spring together due to the pull of the spring since, on release, there is suddenly no contact force between the blocks and the surface of the tray. In free fall, the normal contact force between the blocks and the tray becomes zero, and since the size of the frictional force is determined by the size of the normal force, if the latter reduces to zero, so does the former, and thereby provides a beautifully simple demonstration of the effects of weightlessness. See Zetie (2004).

[1] Mathematically, the *floor function* $\lfloor x \rfloor$ gives the largest integer less than or equal to x.

The lasting allure of electromagnetism

Many simple experiments exploring electromagnetism can be performed using readily available materials. Here we describe two such experiments. Many others have already been previously described by one of us (Stewart, 2005a).

Magnetic force on two current-carrying metallic strips

Current flowing in a wire creates a magnetic field in the space surrounding the wire. Two current-carrying wires near one another will therefore experience a magnetic force due to the interaction between the two magnetic fields resulting from the current-carrying wires. The magnetic force is attractive when the currents in the wires flow in the same direction while it is repulsive when the currents flow in opposite directions. Hang two long narrow strips of aluminium foil vertically so that the end of each strip is supported such that it has sufficient freedom to flex a little from side to side under its own weight. The supported strips should be relatively close to one another but should not touch. Using alligator clips, attach a wire to each end of the aluminium strips which are, in turn, separately connected to their own power pack. On allowing separate currents to pass through each of the strips, the strips will be observed to either repel or attract one another depending on the respective current flow directions.

Magnetic dragging and braking

A change in magnetic flux through a conductor induces an emf equal in magnitude to the rate of change of the flux through the conductor in accordance with Faraday's law. If the conductor forms a closed circuit, by Lenz's law an induced current will flow in such a direction as to oppose the change which caused it. If the conductor happens to be extended, the induced currents are able to circulate in the body of the conductor and are known as eddy currents. The interaction between the eddy currents induced in the conductor with an external magnetic field causes a magnetic force to act in such a direction as to oppose the change which caused it. This often leads to either magnetic braking or magnetic dragging. A number of simple experiments demonstrating magnetic braking have already been described previously by one of us (see Stewart, 2005a). The dual case where one observes the resulting magnetic force that acts on a conductor leading to both magnetic dragging and braking will be described here. Take an aluminium or copper disc roughly the size of one's hand with a small hole drilled through its centre. Holding it in the vertical plane with the tip of a ball-point pen supporting it through its central hole, bring a bar magnet which has a neodymium magnet attached to one of its ends up close to the disc. The disc should be reasonably free to spin about its central axle. Start to rotate the neodymium–bar magnet combination in a circle just above the surface of the disc. The disc should begin to spin in the same direction as the direction in which your hand is rotated. Here the interaction between the eddy currents induced in the conductor and the external magnetic field from the magnet leads to the disc being 'magnetically dragged' since a magnetic force acts on the disc in the same direction as the direction of rotation of the magnet above. Rotating one's hand faster causes the disc to spin faster. As an interesting non-trivial test of a student's understanding of both Lenz's law and the right-hand rule, have students predict in advance the direction the disc will rotate. See Stewart (2005b). If the rotating magnet combination above the disc is suddenly stopped, the converse effect of magnetic braking on the disc will be observed since the magnetic force resulting from the interaction between the induced

eddy currents in the disc and the external magnetic field will be in such a direction as to oppose the direction of rotation of the spinning disc.

Interesting curiosities

The next three demonstrations are sure to pique the interest of students and colleagues alike.

Inverted sprinkler
Remove the top part of an aluminium can and with a nail, poke four holes equally around its middle. Dent the holes in such a way that if the can were filled with water, it would spurt out of the can tangentially to the can's surface. Next, connect a string to either side of the top of the can for support. With the can completely filled with water observe the direction the can rotates as the water spurts from the four holes positioned around its middle. Since the water is pushed radially out of the can through the holes as a result of a pressure difference between the inside and the outside of the can, as it leaves the holes, it exerts an equal but opposite force back on the can, which causes the can to rotate. Now reverse the situation by placing the same can, which is now empty of water but slightly weighted at its bottom, and immerse it in a bucket of water. The can should initially be immersed in the bucket so that the water level just covers the four holes around the can's middle. Now ask students in which direction they expect the can to rotate as it fills compared to its previous direction of rotation. As the water enters the can it will now rotate in a direction opposite to the previous case, since this time round the entering water exerts a force on the can in a direction which is opposite to that of the exiting water. See Hewitt (2004). This problem has a long and distinguished history in the literature and is often referred to as the *Feynman inverse sprinkler problem* after Richard Feynman, the famous physics Noble laureate who pondered it for many years.

Triboelectric charging
A particularly novel way to demonstrate the formation of static charge is to use the phenomenon known as triboelectric[2] charging: charging generated by friction. Sit a tin can on an insulating material, a plastic picnic plate for example. Around its rim attach long, narrow strips of aluminium foil which are roughly equally spaced. Using the top cut away part of a plastic bottle as a funnel, pour a quantity of white sugar through the funnel and into the tin can. The aluminium strips, like the leaves on an electroscope, should slowly rise as the sugar is poured indicating the presence of static charge. Here individual crystals of sugar become charged due to friction with the walls of the funnel as it is poured and become deposited on the surface of the tin can which is a conductor in a phenomenon referred to as triboelectric charging. For further details on this intriguing phenomenon see Planinšič (2004). Triboelectric charging can be particularly hazardous in industry as unwanted static electric charge may build up to sufficient levels which can lead to potentially lethal discharging through sparking occurring.

[2]The prefix *tribo-* is a combining form relating to friction and comes from the Greek *tribos*, meaning 'rubbing'.

Shrinking coin

This is more a topological trick in non-Euclidean geometry than a demonstration, but one which nonetheless has an interesting application to the more intellectually taxing field of string theory! Take a piece of paper with a small circular hole cut from its centre and ask an unsuspecting student (or colleague) to try and pass a larger circular disc (or coin) through it without ripping or tearing the paper. In moving from Euclidean geometry in the plane to non-Euclidean geometry in space, the piece of paper can be folded in such a way to allow the larger coin to pass through the smaller hole. This is done by folding the paper containing the circle exactly in half and then drawing out either of the semicircular ends so that the curve becomes a straight line. The space the coin has to pass through the circle is thereby increased from a length equal to the diameter of the circle to one which now equals half the circumference of the circle, an increase in length by a factor of $\pi/2$, or roughly one and a half times larger! This clever little trick we first saw described in the Institute of Physics *Physics Tricks* (2005). Here they suggest that the trick could be used as a way of introducing how multiple dimensions can be folded into tiny spaces, an idea particularly useful in aspects of string theory where the concept of folded dimensions arises.

An aluminium rod will suffice

The difference between longitudinal and transverse waves, resonance modes of vibration, and the Doppler effect can all be demonstrated in a simple fashion using a long, solid aluminium rod. All the demonstrations that follow have been inspired by Gluck (2005).

Longitudinal and transverse waves

Using a solid aluminium rod (we use a rod of length two metres and diameter of about half a centimetre) and holding it in the horizontal plane at its centre, squarely strike one end using a hammer. A typical sound due to longitudinal vibrations in the rod will be heard and will persist for some time. Now strike one end of the rod perpendicular to its length. A different sounding sound of a different pitch resulting from transverse vibrations in the rod will now be heard.

Fundamental and overtone modes of vibration

Holding the rod in the vertical plane at its centre with one hand, strike its end nearest the ground by hitting it hard against the ground (the ground here needs to be a concrete or hard tiled surface). Longitudinal vibrations will once more be set up in the rod. The vibrations in the rod do, however, not only contain the fundamental mode of vibration but also contain several higher overtones. To find which overtones are present, we mark the rod off at lengths equal to $L/4$, $L/6$ and $L/8$ from the top. Here L is the length of the rod. After its bottom end has been struck against the ground with one holding the rod at its centre, such a point must be a nodal point and the fundamental mode of vibration dominates. Suddenly transferring your hold to $L/6$ with your other hand suppresses the fundamental mode as it has an antinode at this position. A sound of a higher pitch but lower intensity is still heard to emanate from the rod and is the weaker second overtone of vibration (note that this overtone also has a nodal point at the centre of the rod). Alternatively, if one moves one hand from the centre to the position at $L/4$,

both the fundamental and the second overtone become suppressed since each of these modes has an antinode at this position and as a result no sound will be heard. Note that it is not possible to set-up the first overtone mode of vibration in the rod if the rod is initially held at its centre when its bottom end is struck since such a mode must contain an antinode at the centre of the rod. To establish a mode of vibration corresponding to the first overtone in the rod one must instead hold the rod at the position marked $L/4$ before the rod is struck as this point corresponds to a nodal point.

Doppler effect

Holding the rod at its centre and in the horizontal plane, again strike one of its ends so that the rod begins to resonate. Moving the radiating rod quickly towards and away from the class will result in a Doppler shifted sound being heard. Here one has a stationary observer and an approaching and receding sound source.

Conclusion

Physics is hard, its concepts are difficult, not obvious, and often seem to be counter-intuitive. Students come to us with fully developed alternative notions and conceptions that do not always agree with those scientifically accepted. Correct, perceptible awareness of physical phenomena does not come readily but instead requires a particular habit of mind which the unacquainted finds alien and unfamiliar. Simple demonstration experiments are one epistemic tool the teacher has and can use to expose and help aid understanding in the learner of the principles and concepts of physics. In this paper we have tried to present a collection of demonstrations we feel make for the simplest and most elegant way to show or confirm a particular physical principle. From the simplicity and convenience of the demonstrations described, it has been our intention to hopefully promote and encourage many more teachers of physics to use simple demonstrations as a natural and integral part of their own teaching; to not do so would be to fail by our students.

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Computing

Using S5 for presentations: A credible alternative to PowerPoint?

M. Nystedt

Higher Colleges of Technology, Abu Dhabi Women's College, Abu Dhabi, United Arab Emirates

Abstract

S5 is a way of creating and showing presentation slide-shows using personal computers. It is based on open Internet and web standards and is open source and cross platform, which means S5 has many attractive benefits. This paper is a combination of a tutorial on how to create S5 files and an overview of the benefits, drawbacks, and practical implications of working with S5 as compared to dedicated presentation software such as Microsoft PowerPoint.

Introduction

In most of the courses that I teach, I have students make presentations of some sort. They can be of papers they have written, projects they have worked on in groups, a website they are critiquing or something else. Usually I leave it up to them to decide if they are going to use some form of presentation software or not, and if they do, it is always Microsoft PowerPoint. I say always because in my ten-year teaching career in higher education, I have yet to see anything else but PowerPoint used for presentations by students. In the same way Google has become synonymous with searching for information on the web, PowerPoint has become synonymous with presentation software. People 'Google for information' and they 'create PowerPoints', instead of searching the web and creating presentations.

Perhaps early on in this paper, it should be noted that presentation software can easily be over-used and indeed abused. How many of us have not suffered through content-less presentations overloaded by effects, pictures, fonts, and colours? Using presentation software in an effective and efficient manner is an art in itself and it is beyond the scope of this paper to even approach the subject. If my students ask me before a presentation whether they should use PowerPoint, I typically answer, if it 'makes sense' for the presentation being made. The important thing is to get them to think about what is good and bad about using presentation software and get them to practice using it.

Introducing S5

In late 2004, Eric Meyer made one of his latest creations available on the web. S5, short for 'Simple Standards-based Slide Show System', was released as open source.

It is available for anyone who wants to experiment with new ways of doing presentations with computers.[1] S5 is really a framework or template with which users can create slide-show presentations using web-based technologies such as XHTML, CSS and Java-Script. S5 slide-shows can be created with very low-end equipment – all that is needed is a text editor – and the slide shows can be presented with just a web browser. In short, there is no need for particular software during creation or presentation. In Eric Meyer's own words

> S5 is a slide-show format based entirely on XHTML, CSS, and Java-Script. With one file, you can run a complete slide show and have a printer-friendly version as well. The markup used for the slides is very simple, highly semantic, and completely accessible. Anyone with even a smidgen of familiarity with HTML or XHTML can look at the markup and figure out how to adapt it to their particular needs. Anyone familiar with CSS can create their own slide-show theme. It's totally simple, and it's totally standards-driven. [Meyer, 2005]

Structure of S5 presentations

An S5 presentation consists of one XHTML file that contains the actual slide content, a number of CSS style-sheet files, and a Java-Script file. The Java-Script file takes care of the functionality of the presentation and the CSS files control various aspects of layout. For example, there is one CSS file for printed-out presentations and one for on-screen presentations. There are also a number of themes available that you can download and apply to your presentations. By using a theme, you can quickly change the look of a presentation without having to touch the actual content. The XHTML file is the actual content in terms of text on the slides. The design is separate from the content because it exists in other CSS and Java-Script files. When you apply a theme, you keep your XHTML file and replace all other files thereby changing the look of the presentation while preserving the content. A closer look at the XHTML presentation files reveals how easy the structure and information really is. In the <head>-section of the XHTML file you will find information such as presentation title and author. See Figure 1.

Looking at the actual code for the slides in the presentation also reveals the simplicity of S5. Figure 2 shows the code necessary to set up the presentation. As you can see in the source code, much of it you should not edit. In this example it is only the '[location/date of presentation]' and '[slide show title here]' that you should change.

In a presentation, the first slide, usually referred to as the title slide, contains information about the author, their affiliation, and of course the title of the presentation. In the S5 XHTML file, the code shown in Figure 3 controls the first slide of the presentation.

To give you an idea of what you have to do in order to create a slide for a presentation using S5, Figure 4 gives an example. It is a traditionally formatted slide with four bullet points on it. If you are concerned about typing in all of the XHTML code for every slide, you can start off with an empty template file and just copy and paste the standard codes. That way you only have to fill in your content and not worry about the

[1] S5 can be downloaded from `http://meyerweb.com/eric/tools/s5/`

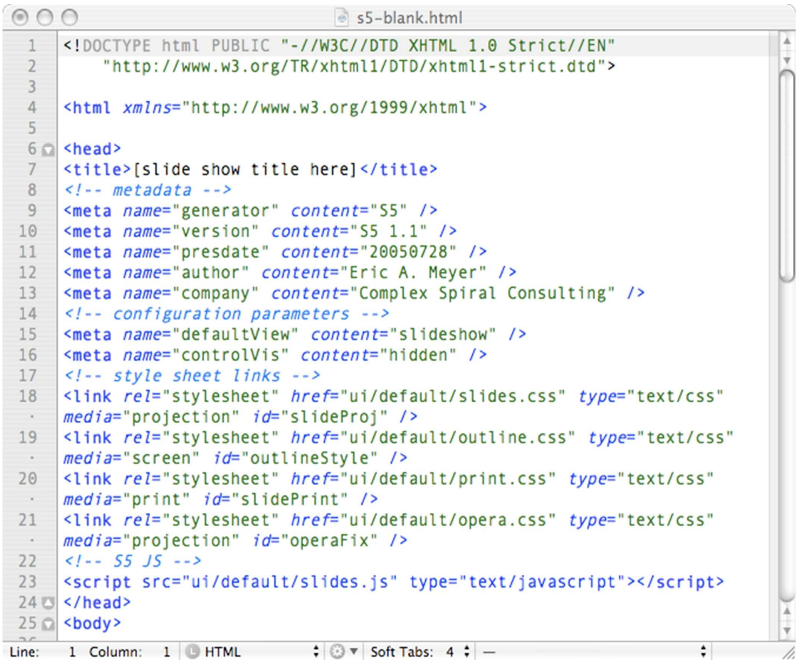

Figure 1: XHTML file which controls the presentation.

XHTML. The code in Figure 4 will look like Figure 5 when you load the S5 presentation in a web browser.

Benefits

There are numerous benefits to using S5 for presentations. One of the main ones in my view is that S5 does not require particular software to create the presentation files or to display them. Any software that can create a simple text file will do fine. For all Windows users, that means Notepad will suffice. To run the presentation, all you need is a web browser which almost everyone has on his or her computer today. One aspect of S5 that really attracts me is that it is based on web-standards, making it portable and cross-platform.

S5 presentations can be displayed online or locally. Without exporting, the same presentation can be put on a web server or just kept on the local computer. There is no need to export a presentation to a web format, thus saving time for the author. S5 presentations are lightweight and compact. Obviously, if you add a lot of large pictures, video, etc., the size will grow, but in my experience, they do not become as large as PowerPoint files for example.

Depending on how you use a computer in your classroom, switching between presentation software, web browser, and other software can become a hassle. I use a web browser in many of my classes. Switching between presentation software and the web

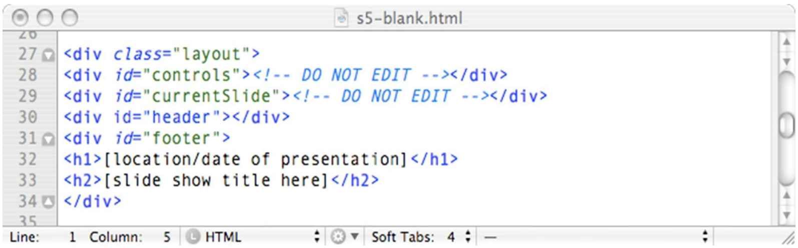

Figure 2: Code for the entire presentation.

Figure 3: Code for the title slide.

browser becomes frustrating after a while. It often happens that while in the middle of running a presentation I want to switch and search for something using a web search engine. Afterwards, I have to go back to the presentation software and restart the presentation. With S5 I keep the presentation in one tab in the web browser (using Firefox for example) and do whatever else in the other tabs. Switching back and forth is as easy as switching tabs. For me, this is an often much overlooked benefit of using something like S5.

Many teachers and other presenters print out their presentations and hand them to their audience beforehand. Software like PowerPoint offers many formatting options for printing handouts. S5's options are limited but by using a special CSS style-sheet for printing a presentation can automatically be formatted for printing.

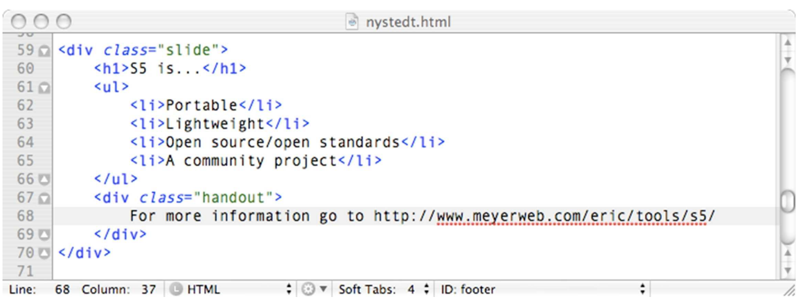

Figure 4: Example slide with four bullet points.

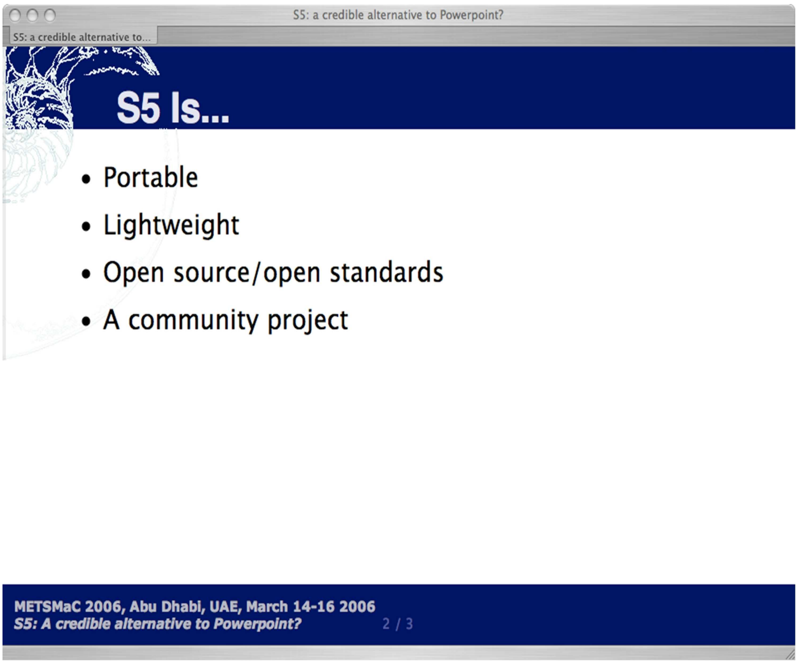

Figure 5: Example slide.

S5 offers centralised layout management. An organisation could create one S5 theme, upload it to a web server and let everyone in the organisation use the same theme. Users would not even have to download it to their computers, but could just point the S5 XHTML file to where the theme is stored on the web. This works in much the same way as web sites that use a coherent look and feel from templates and themes.

Drawbacks

Arguably, the most obvious drawback of S5 is that it requires some technical knowledge to use, at least until better authoring software is developed. This means that S5 is probably not ready to be adopted by the large mass of users who currently work with PowerPoint, but at the same time, it is easy enough that many could convert. Let us not ignore the fact that many users already know PowerPoint and PowerPoint is, for better or for worse, the de facto standard.

For many users the fact that S5 does not support slide transitions and some other multimedia effects will mean it is not an alternative for their presentations. My feeling is that for most presentations, especially in academic situations, these things are not really necessary, often over-used, and indeed abused.

One of the major drawbacks with an S5 presentation is that it does not scale to fit different monitor resolutions. Presentation software usually automatically scales up or down to fit different resolutions, so slides look good in both 800x600 and 1024x768 for

example. S5 automatically scales text up or down but not pictures. If a 500x300-pixel picture fits well in a 1024x768 slide, it might not fit at all at lower resolutions. If you know the resolution beforehand, it is not much of a problem and if you work on the same resolutions most of the time, S5 works fine. On the other hand, if you often have to change display resolutions and use many pictures in your presentations or do not know the resolution beforehand, then S5 will be hard to work with.

While considering these drawbacks, let us also remember that S5 is under development. New versions are introduced at fairly short intervals and new features are added all the time. At the time of writing this paper, the most recent version of S5 is 1.1, but you can already try a beta of a newer version.

Conclusion

My first experience with S5 was at a conference in February 2005. I presented a paper and created my presentation by typing the text for my slides in a text editor on my Apple Powerbook which made the creation process fast. Since then I have ventured into creating my own templates and I have used S5 extensively in my teaching.

In my brief experience with S5, the main drawback has been that it does not scale automatically to different screen resolutions. Since I have presented at different venues, with different projectors and different computers, this has meant that sometimes pictures do not fit or they appear too small. If that problem could be alleviated and there was a good editor for creating S5 files, I would be 100 per cent behind using S5 for all my presentation needs. As it is, S5 has come a long way in a short time and it is a good solution for some situations, but it obviously has some growing to do. Let us remember that S5 is not meant to be a direct competitor with dedicated presentation software like PowerPoint, but rather a complement. In conclusion, S5 certainly is not for everyone and it will not suit all situations, but for many presentations it can be an attractive alternative. It requires less in terms of both hardware and software and although it requires some technical expertise to create presentations with S5, for most users it is easy enough. As more software becomes available that can create S5 presentations in a more user-friendly way, I am sure more users will adapt this new way of creating and presenting slide shows.

Reference

MEYER, E. (2005). *S5: A simple standards-based slide show system* [online].
Available from: `http://www.meyerweb.com/eric/tools/s5/`

Integrating curriculum in an interactive multimedia environment

Darlene Liutkus

Al Rabeeh School, Abu Dhabi, United Arab Emirates

Abstract

In recent years, educational researchers claim that there are chasms between disciplines that are caused by 'differences in notation, terminology, and emphasis' which, have resulted in students perceiving topics as isolated compartments thereby creating a lack of ability to transfer knowledge from one context and apply it in a different situation (Frair and Rogers, 1997). The solution to closing this chasm is to integrate curriculum which creates an environment where students 'might more easily and effectively assimilate new information if topics presented simultaneously in different courses were closely related' (The Foundation Coalition, n.d.). Theorists have posited that curriculum integration is a way of organising 'common learnings' through real-life problem-based activities (Vars and Beane, 2001). To eliminate such chasms in education, how can curriculum best be integrated? Should it be done in a constructivist environment? Would using problem-based learning be instrumental in achieving integration? Can multimedia applications assist in developing cross-curricular activities and be an effective tool for learning? This paper will take a look at a theoretical process of integrating curriculum that effectively includes multimedia applications.

Introduction

Researchers have indicated that students have been unable to transfer their higher order skills from the classroom to real-life situations. It has been noted that 'traditional approaches to university education promote subject-based learning... which fails to integrate knowledge' (Albion and Gibson, 1998b). In order to close the gap, organisations and institutions have concluded that there is a need to integrate curriculum. While education has begun a path towards integrating curriculum to solve the problem of transference of knowledge by presenting students with constructed learning activities that acknowledge other topics, the move towards using computers in the classroom is still prevalent. In many school divisions, increased pressure is being placed on teachers to integrate technology into the classroom (Albion 1999a). One solution is to marry the transference of knowledge and technology integration by designing a problem-based culminating project to be applied in the classroom under the direction of the teacher that utilises multimedia applications.

What is an integrated curriculum?

Many post-secondary educational institutions are moving towards providing their students with problem-based education that transfers subject content to real life scenarios as a way to reinforce cognitive awareness. Mehriban Ahmadova in her paper, *Curriculum design, new approaches*, cites several definitions of integrated curriculum:

> ‘Integrated curriculum is education that is organised in such a way that it cuts across subject-matter lines, bringing together various aspects of the curriculum into meaningful association to focus upon broad areas of study. It views learning and teaching in a holistic way and reflects the real world, which is interactive’ (Shoemaker, 1989); ‘curriculum organisation which cuts across subject-matter lines to focus upon comprehensive life problems. . . ’ (Good, 1973). [Ahmadova, 2005]

Organisations are becoming aware that there is a link between academic and occupational education as students leaving their educational institutions need to be able to transfer their higher-order thinking skills and processes, such as problem-solving and critical-thinking skills when analysing details, synthesising concepts or validating an explanation. As an example, The American Center for Occupational Research and Development defines an integrated curriculum as ‘a curricular organisation intended to bring into a close relationship the concepts, skills, and values of separately taught subjects to make them mutually reinforcing. . . ’ (Edling and Loring, 1996).

Using problem-based learning to integrate curriculum

Research has shown that since 1945, educational content has continued to be segmented by academic disciplines for a number of reasons. The integration of curriculum is meant to foster the contextualisation of content for the majority of students (Edling and Loring, 1996) as well as having the potential to reinforce students’ acquisition of basic and higher-order academic skills. As a response to the segmentation of disciplines, problem-based learning (PBL) was developed to access knowledge across a range of disciplines (Boud, cited in Albion and Gibson, 1998b). Thus, to integrate curriculum effectively, many professionals have chosen to develop real-life scenarios that present problematic simulations on which teams of students must apply their prior knowledge to mediate a solution, thus improving their problem-solving strategies (Albion and Gibson, 1998b).

If integrating curriculum is best implemented using PBL then designing an authentic culminating project in a multimedia environment to support it is a logical move (Albion and Gibson, 1998a). Grubb, Davis, Lum, Phihal and Morgaine (cited in Paris, 1998) have suggested that students complete a project that shows mastery of several competencies. They claim that, in some schools, this project involves a physical representation requiring the use of vocational shops, a written paper, and an oral presentation. The project is usually completed during the final year and is considered a capstone achievement. In preparation for this project, students learn various skills such as working independently, receiving hands-on experience in various vocational shops, doing research, solving problems, and presenting findings.

Designing a project to integrate curriculum

The foundation of this discussion rests on the theory that debate on the role of multimedia should be supporting, not controlling, the learning process. Design and implementation issues have already been identified when developing a stand-alone multimedia product (Albion and Gibson, 1998b) so having students work independently, removed from instruction, could present problems.

To begin the process of integrating curriculum it is necessary to identify critical issues that will address not only the learners' and teachers' needs, but also the legislated standards, and expectations or outcomes required of the curriculum. With this in mind, the development process should consist of the following primary considerations:

- Role of educational pedagogy – instructivist, constructivist, and problem-based learning.
- Role of the student – thinking processes, active not passive.
- Role of the teacher – integration of technology, move from teacher to facilitator.
- Role of multimedia – effectiveness, manipulative ability.
- Role of ministry guidelines – standards, outcomes, expectations.
- Role of assessment – making it authentic.

Researchers of integrating curriculum agree that the above considerations are essential components. Each will be now taken up and discussed individually.

Role of educational pedagogy

Before integrating curriculum it is necessary that the learning environment begin at the individual core subject area. Teacher instruction of the content is essential in order for the student to receive the fundamental components of a subject before becoming an expert. The learner, at this stage, is often thought of as a passive recipient of instruction but that does not have to be the case as described in the role of the student. However, early in the development process each teacher must work independent of the other to ensure full dissemination of content. Pedagogy, then, could be considered to be 'instructivist'.

In keeping with the problem-based learning philosophy where the problem drives the learning, students can be taught both the lower order and higher order skills concomitantly by practising and applying concepts with an authentic learning task. Authentic learning means learning that uses real-world problems, or projects that allow students to explore and discuss topics in ways that are relevant to them. They will become active in the learning process by applying problem solving in context, which will assist them in developing their skills.

Topics and units are taught independently, but they are arranged and sequenced to provide a framework for related concepts. The students can gradually progress to an even more complex version as each task is mastered. In this 'microworld' (Stoney and Oliver, 1999) students will have begun to transfer knowledge inside the core subject classroom. This learning environment should be active, co-operative, self-assessed,

provide prompt feedback, allow for a better opportunity to account for personal learning preferences, and be highly effective.

Role of the student

The student's role must become more assertive so they do more than passively sit and listen to their teacher talk. They must be active participants in the learning process, by writing, discussing, analysing and evaluating information. They need to be metacognitive of their learning process.

The student should understand what must be mastered by accomplishing goals and applying prior knowledge to develop higher order skills through directed learning activities provided by the teacher. With activities such as case studies, the student should be able to analyse complex situations that involve conflicting goal-criteria and complex casual factors. They should solve problems ranging from simple to complex that are solvable by known methods or improvisational creativity.

Reflection activities directly involve the student by developing cognition through educationally useful experiences that will help them learn more from their experience and will remember or transfer to new situations. In short, students must take more responsibility for their own learning, and demonstrate it to their teachers in ways other than on a test.

Role of the teacher

In order to address the needs of the students, a learner-centred approach in the classroom is recommended. The teacher must be aware of students' respective knowledge, skills, attitudes, and beliefs. Not only should the teacher act as subject expert but he or she should encourage students to ask questions, engage in social discourse, and find their own answers. In this setting, the role of the teacher moves more to that of a 'co-constructor of knowledge' (Peters and Armstrong, 1998) than a giver of content. Teachers should help students make connections by explicitly making linkages between subject topics, skills, and concepts. Designing authentic learning activities will ensure that the student becomes and stays involved in their learning.

Laurillard's (1993) development of the teaching and learning process is helpful in having the students actively engage in their learning through (i) discussion, where the teacher provides a meaningful task so that the student is able to articulate an understanding of the content; (ii) interaction, where the student achieves a goal while the teacher provides important feedback on their accomplishments; (iii) adaptation, where the student is able to apply their knowledge to achieving the task; and (iv) reflection, where the student would re-visit the process of understanding, applying and achieving the task presented.

Teamwork is essential when developing an integrated project. Teachers must collaborate on a regular basis to ensure they are focusing on the integration by listing and ranking topics, concepts, and skills to organise curricular priorities systematically within each subject. Teachers can then find topics that are arranged around commonalities and emergent patterns. This process blends the disciplines by finding overlapping skills, concepts, and attitudes found across the disciplines. Finally, the teachers must

select an appropriate multimedia application that would best suit the demonstration of the students' acquired course skills.

Role of multimedia

Effective educational multimedia must have the capability of allowing students to manipulate exploration within its environment. It is vital that the student be able to achieve the cognitive objectives required by the curriculum through manipulation of the software. A set of usability heuristics has been published by Nielsen (1994) that will optimise effectiveness. Specifically, for use in this discussion are (Squires and Preece, 1999):

- Match between the system and the real-world.
- User control and freedom.
- Consistency and standards.
- Flexibility and efficiency of use.
- Help users recognise, diagnose, and recover from errors.

Since that time, other authors have expanded upon the above list. Further to this discussion are (Albion, 1999b):

- Elicit learner understandings.
- Support for transference and acquiring self-learning skills.
- Support for collaborative learning.
- Relevance to professional practice.

The multimedia selected by the teacher should not be an object of evaluation unto itself but rather it should be a tool that will allow the student to demonstrate through manipulation the knowledge they have acquired throughout the course.

Role of ministry guidelines

Curricula outline clear and detailed curriculum expectations, that is, the particular knowledge and skills that students are expected to demonstrate by the end of each course. In addition, for every discipline, there are generally descriptions of achievement levels which are meant to assist teachers in their assessment and evaluation of students' work. When designing an authentic integrated project, each teacher must be aware of which expectation(s) or outcome(s) is/are required in order to display student knowledge and level of ability. Assessment should remain in a context familiar to the students. The final project will act as an extension to the classroom learning activities.

Role of assessment

Assessment in a variety of forms should be built into the teaching and learning process to monitor student progress in real time and provide assistance and alternative methods to overcome difficulties. A student's progress should be documented throughout their work on the project to reflect their learning over time. This assessment should help to build mastery of the subject by students, allowing them to revise their work and incorporate new understandings and constructive feedback.

Assessment should be authentic in a problem-based project. In order for the student to construct meaning they need to be clear of learning outcomes. Creating rubrics for evaluating student work helps to determine the criteria required by the curriculum and what is expected of the student. There are additional benefits to creating a rubric with the class. Students will not only understand, but be actively engaged in the process of determining the criteria used for their assessment. As an assessment tool, rubrics allow for complex critiques of multimedia projects, presentations, and written reports. Since the criteria for assessment is clearly defined, teachers and students share a common understanding of the project goals and criteria, and the various levels of completing the defined criteria.

Putting theory into practice

Once having established the primary needs, a logistical process of development should take place that will move the learner from a passive recipient of instruction to one who constructs their own knowledge through practical implementation of the concepts. To illustrate, reference will be made to a project developed at a local institution in the 2004–2005 academic school year.

Early in the school year a team of teachers gathered together to develop a project that would 'blend' their curricula in an authentic problem-based project which would allow students to demonstrate their accomplished course outcomes. Involved were the following subject areas: Mathematics, Electronic Engineering, Computer Programming, and English. The students took these courses concurrently, which were presented in the conventional format. Central to the project was the use of multimedia to demonstrate their expertise and deliver a presentation displaying their outcomes.

A core component of a problem-based learning environment is that of cognitive dissonance and the negotiation of meaning. Furthermore, essential to a successful integrated project is that the problem must be integral to each subject. In this particular situation, there was an engineering design project that required more than a synthesis of previously learnt knowledge. Hence, both critical attributes were accomplished. The project required the student to build a dual voltage circuit both physically and virtually, write a program that would analyse the workability of the circuit and confirm that all was correct, then present their circuit and how it was made to convince others of its authenticity. The multimedia involved in this project was: Electronic Workbench, C++ Programming, MS Excel, MS Word, and MS PowerPoint.

The project was developed so that the students were in a continual process of 'constructing, interpreting, and modifying their own representation of reality' (Jonassen, cited in Harper and Hedberg, 1997) based on their experiences through actually making and confirming a dual voltage circuit. The students were left to generate their own

strategies for working out a solution and they were able to challenge their thoughts, beliefs, perceptions and existing knowledge by collaborating with other students.

Assessment was rubric based. Each subject teacher made clear to the students the expectations and outcomes that were required for them to achieve success. For instance, the mathematics teacher focused on how the students used matrices to authenticate the circuit while the electronic engineering teacher evaluated the physical and virtual circuits. Presentation was made before all teachers as they individually assessed their students based on the agreed upon course rubric.

Upon conclusion of the project, all teachers were satisfied that this type of project was successful in allowing the students to demonstrate their comprehension and learnt expertise in each subject area.

Conclusion

A constructivist environment is beneficial for the successful acquisition of skills required by a curriculum. Implementing a problem-based learning environment to integrate not only curriculum but also technology into the classroom is one effective solution for present day educators. Further, a well designed authentic learning project will encourage the learner to seek out information necessary to achieve the expectations set out by the curriculum. Selecting appropriate and effective multimedia will motivate them to articulate what they know, demonstrate their abilities, and refine their knowledge. Finally, constructively integrating multimedia applications with curriculum content through an authentic project will enhance a student's transference of knowledge and skills from one classroom to another and hopefully into the real world.

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Bootstrap and other methods to measure learning in UAE universities and higher colleges

Djamel Bellout[1], H. Harbi[2] and Khaled Hamdan[2]

[1] *Department of Statistics, College of Business and Economics, United Arab Emirates University, Al Ain, United Arab Emirates*
[2] *Information and Communication Technology Department, University General Requirements Unit, United Arab Emirates University, Al Ain, United Arab Emirates*

Abstract

This work is concerned with how to measure the 'amount of learning' in problem-based learning programmes, and the factors that affect it. Due to difficulties in describing quantitatively such educational aspects as learning, which are rather abstract when it comes to measuring, this is a non-standard problem in which some indirect estimation methods and other tools are used. On the other hand these methods require very little mathematical background or assumptions, but rely on the computational power of a computer instead. The Bootstrap is one of these methods that is widely used nowadays. The approach is general, yet simple and instructive.

Introduction

A common practice among curriculum developers today is to itemise the assessment of learning by what is called 'learning outcomes'. These are achievable through the development of skills among other means. Then comes the evaluation at the end of the learning cycle, in terms of performance scores or levels through tests, surveys, or other tools. But usually research studies about the process above end up answering the basic questions of whether learning occurred or not, and to what extent, if it did. In other words, they provide qualitative statements about it. What about the question 'how much'? In this work, we attempt to treat learning more objectively by describing it quantitatively despite its nature which is rather abstract when it comes to measuring. In the second section of this paper we examine the possibility of giving a meaningful sense to 'measuring' the amount of learning which we interpret in a particular way. The third section turns the measurement problem into a prediction problem given the fact that this is done ahead of time. It also displays the factors (attributes) related to learning, which we have used in the analysis. In the fourth section, the data structure is presented as well as the statistical methods used, and the indirect way in which the estimation procedure was conducted is revealed. The Bootstrap method is presented in

general terms, and the overall algorithm of this prediction procedure is displayed. The fifth section is dedicated to the detailed application of the procedure exposed in the previous section to a dataset of about fifty-six Mathematics/IT sections collected at the end of autumn 2005. The sixth section contains a few remarks about the advantages, limitations, and drawbacks of this methodology and closes with a conclusion in the final section.

Measuring learning

Teachers and researchers interested in learning assessment typically analyse different aspects of student learning through subject specific tools using one variable at a time. In fact, many of them direct their assessment or analysis of student learning towards proving the superiority of their educational 'prophecies' and their curricula, as pointed out by Hattie (1999). The authors of this paper, and others, call for a more rational treatment of student learning through more rigorous and objective models integrating effect magnitudes of learning related factors, based on appropriate statistical analysis.

In other words, we want to 'measure' (estimate) the impact of the factors most significantly related to student learning. Now, what if one could come up with a 'summative measure' integrating all these important aspects of student learning? The abstract nature of learning as an entity, when it comes to measuring, makes this a difficult task. This requires one to agree on an answer to the question 'what is learning in education?'

To get a feeling of the diversity of theories built around the concept of learning, one is directed to the twelve commonly known theories of constructivism, behaviourism, right brain/left brain thinking, and so on.[1] A somewhat simplified definition taken from the Internet[2] reads as follows

> Learning is the process of acquiring knowledge or skill through study, experience or teaching. It is a process that depends on experience and leads to long-term changes in behaviour potential.

So it seems that learning is perceived as a process rather than a 'measurable quantity'. This motivates our attempt to 'measure' the 'amount of learning' (rather than learning) through some of its many aspects.

The 'amount of learning' is not a new idea. Flueckiger (1976, 1978), and others, treated it from an economics point of view. Flueckiger related it to technological change and 'optimised' it by deriving 'learning curves' based on a theory called finite automata. Again, because of the abstract nature of learning, this measure is done via an indirect estimation process based on 'case based reasoning'. The next question is therefore 'should learning be measured (quantitatively) or described (qualitatively)?'

As mentioned earlier, ideally one would hope to come up with a 'summative measure' integrating all these significant aspects of student learning. How this 'summative measure' combines these factors is yet another issue! In the meantime we could think as follows: for these learning aspects (combined in some way or taken one at a time), consider the amount of learning achieved at the end of the learning cycle as the

[1] See `www.funderstanding.com` for further details.

[2] See `www.reference.com`.

'amount of knowledge produced by the students as a per cent of the amount of knowledge received'. For now, a quantitative approach to measuring such an entity is not obvious! One way out is to rely on the subjective judgment of the teacher. One could even turn this percentage of produced knowledge into a five or more point scale. Given that we possess such information for historical cases, our idea consists of predicting the 'amount of leaning' to be achieved by a new case (a new section in our study) on the basis of values of this response variable, obtained for historical cases which are similar to this one according to selected attributes.

Predicting learning through related factors

Suppose that, at the beginning of a semester, for pedagogical and/or research purposes, a teacher or researcher wishes to predict the 'amount of learning' that one of his or her sections would accumulate at the end of a semester.

We propose a solution based on historically similar cases (sections) extracted from a database containing, in addition to the amount of learning, information on a panel of quantitative and qualitative variables (attributes) from previous semesters.

Data structure
Characterise the new case (section) according to the panel of attributes used (factors) and place it into a historical dataset The data structure would look like the following.

	Learning amount	Attribute 1	Attribute 2	$\cdots$	Attribute k
Case 1	E_1	X_{11}	X_{12}	$\cdots$	X_{1k}
Case 2	E_2	X_{21}	X_{22}	$\cdots$	X_{2k}
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
Case n	E_n	X_{n1}	X_{n2}	$\cdots$	X_{nk}
New case	Unknown	Y_1	Y_2	$\cdots$	Y_k

Table 1: The data structure.

Attributes (factors) used in the analysis
In addition to the amount of learning (as a percentage), our dataset comprised sixteen factors.

- Subject (1 = IT, 2 = Mathematics).
- Teacher's degree area (coded 1 to 7).
- Teacher's experience (number of years).
- Class size (number of students).
- Teacher lecturing.
- Tasks (worksheets).
- Collaborative/group learning.

- Student research.
- Student-centred activities.
- Use of teaching aids.
- Computer assisted learning.
- Focus attention on subject.
- Use of incentives.
- Diversify activities and learning styles.
- Encourage student involvement.
- Stimulate student awareness of their role.

The last twelve are all on a 5 point scale with 1 = Always; 2 = Often; 3 = Sometimes; 4 = Rarely; 5 = Never.

Statistical tools and other methods

Some statistical techniques commonly used in economics and which may well be used in this context include

- Expert judgement (experience based estimation).
- Statistical models such as regression or time series analysis.
- Estimation by analogy – Case Based Reasoning (CBR) – comparison.

The last one is used at the beginning of our algorithm. Its different steps are described next.

Steps of CBR

- Case representation.
- Data storage of past cases.
- Retrieve similar case data based on a selected metric.
- Use retrieved case data to solve the new case problem.

Examples of similarity and dissimilarity criteria (metrics) follow.

$$d_{\mathrm{new},i} = \left\{ \sum_{j=1}^{k} w_j^2 (Y_j - X_{ij})^2 \right\}^{1/2}, \quad i = 1, 2, 3, \ldots, n.$$

$$Y_j - X_{ij} = \begin{cases} 1, & \text{if} \quad X_{ij} \neq Y_j, \\ 0, & \text{if} \quad X_{ij} = Y_j. \end{cases}$$

For other metrics and more details on this technique, see Angelis and Stamelos (2000).

The cases (sections) obtained by the application of the CBR method to our dataset constitute the basic sample to which the Bootstrap techniques were applied to come up with the estimates of the precision (standard error), as well as the bias.

Bootstrap technique

This is a statistical concept introduced by Efron in 1979 (see, for example, Efron and Tibshirani (1993)), where it was mainly aimed at estimating standard errors and other statistical accuracy measures, requiring little theoretic knowledge (probability). It was based upon:

- The plug-in principle.
- Replicating the statistic (estimator) used, by repeated sampling with replacement and same size, from the original sample.
- The standard error of the replications.

How does Bootstrap work?

Say a parameter $\theta = t(F)$ is estimated by $\widehat{\theta} = s(x)$ on the basis of a random sample $x = (x_1, x_2, \ldots, x_n)$ from the probability distribution F. The procedure used by the Bootstrap to estimate the standard error of $s(x)$ is outlined in Figure 1.

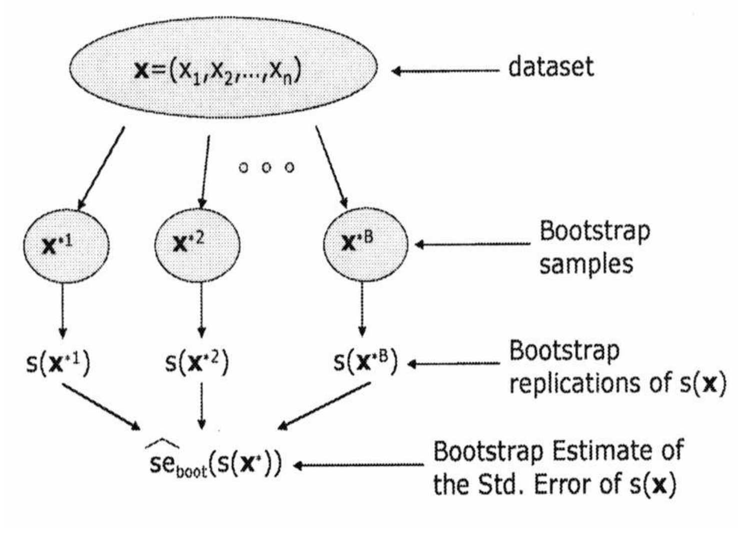

Figure 1: The standard Bootstrap chart.

Here $\widehat{\mathrm{se}}_{\mathrm{boot}}(s(x^*))$ is the sample standard deviation of $s(x^{*k})$, $k = 1, \ldots, B$.

How good is Bootstrap?

Generally, Bootstrap gives good results for B (number of replications) between 25 and 200. For the Bootstrap standard error estimate, it is proved that

$$\widehat{\mathrm{se}}_{\mathrm{boot}}(s(x^*)) \underset{B\to\infty}{\Longrightarrow} \mathrm{se}_{\widehat{F}}(\widehat{\theta}^*).$$

Here $\widehat{F}$ is the empirical distribution, and the limit of the left side is the ideal estimate of the standard error of $s(x^*)$. In fact, the success of the Bootstrap is partially due to the fact that $\widehat{F}$ is consistent for F. In some cases the Bootstrap does not work, for example, in the estimation of θ when $F = U(0, \theta)$.

Predicting the amount of learning: The procedure

The techniques introduced above are implemented in the following four-stage procedure.

1. Extraction of similar cases. Apply software to extract (from a database where the information is stored) the historical cases that are most similar to the current one according to a selected metric.

2. Estimate the response variable 'amount of learning' for the new case (by EBA) based on the cases selected in part 1.

3. Estimate the precision and validate.

   (a) Algorithm: Bootstrap estimate of the standard deviation.

   - Store the data (amount of learning) of the selected cases in a convenient file.
   - Select (with replacement) the Bootstrap samples.
   - Determine the Bootstrap replicates of the median (or the mean).
   - Compute the standard deviation of the Bootstrap replicates of the median (or the mean).

   (b) Algorithm: Bootstrap estimate of the bias and validation.

   - Compute the Bootstrap replicates of the bias for the median (or mean) as the difference between each Bootstrap replicate of the median (or mean) and the sample median (or mean) of the dataset used.
   - Compute the Bootstrap estimate of the bias as the average of the Bootstrap replicates of the bias.
   - Validate by correcting for the bias according to its sign.

An example

The historical cases were represented by fifty-six sections (University General Requirements Unit Mathematics and IT programmes at United Arab Emirates University) from autumn 2005. Part of the dataset is shown in Figure 2. The 'amount of learning' was represented by the column 'summative assessment', and the attributes are the sixteen factors identified earlier.

	A	B	C	D	E	F	G	H	I	J	K	L	M	
1				Students' Learning						Teaching Strategy				
2	TeacherID	Subject	Degree Area	Problem Solving	Information Gathering	Research Project W/P	Communication O/W	Team Work	Summative Assesement	Teacher Lecturing	Tasks (Worksheets)	Collaborative Group	Student Research	St Ce
3	AH	2	7	50	40	60	50	70	80	1	3	2	2	
4	AH	2	7	20	10	50	15	20	70	1	2	3	4	
5	AH	2	7	20	10	50	15	20	70	1	2	3	4	
6	AH	2	7	20	10	50	15	20	70	1	2	3	4	
7	GA	1	3	30	40	25	10	60	80	2	1	2	2	
8	GA	1	3	30	40	25	10	60	80	2	1	2	2	
9	HZ	2	5	20	20	15	10	30	80	2	2	2	2	
10	HZ	2	5	20	20	15	10	30	80	2	2	2	2	
11	HA	1	1	70	80	95	80	95	75	2	1	2	3	
12	GA	1	3	70	50	30	50	60	70	2	1	2	3	
13	MF	1	1	70	80	70	70	80	70	3	2	2	3	
14	MF	1	1	75	80	75	75	85	75	3	2	2	3	
15	HA	1	1	80	80	90	75	90	79	2	1	2	3	
16	HA	1	1	70	80	95	80	95	75	2	1	2	3	
17	HA	1	1	80	80	90	75	90	79	2	1	2	3	
18	SL	1	4	50	0	0	30	30	50	1	2	2	3	
19	SL	1	4	70	0	0	70	60	70	1	2	2	3	
20	SA	1	2	20	10	0	10	20	80	5	1	3	4	
59														
60	New Case	1	4							5	2	1	4	

Figure 2: The dataset.

Extraction of similar cases and estimation by analogy

The following similarity measure was used to extract the most similar cases to the new one (a section other than the fifty-six used as historical cases).

$$\mathrm{Sim}(C_1, C_2, P) = \frac{1}{\sqrt{\sum_{j \in P} \mathrm{F\_Dissimilarity}(C_{1j}, C_{2j})}}.$$

Here P is the panel of attributes, C_1 and C_2 are cases, while

$$\mathrm{F\_Dissimilarity}(C_{1j}, C_{2j}) = \begin{cases} (C_{1j} - C_{2j})^2 \\ 0, \\ 1, \end{cases}$$

such that

1	$=$	Attributes are numeric (A degree of difference between the cases)
2	$=$	Attributes are categorical and $C_{1j} = C_{2j}$ (No degree of difference in attributes)
3	$=$	Attributes are categorical and $C_{1j} \neq C_{2j}$ (No degree of similarity in attributes)

For example, if we apply this to case six with Y being the new case (on the sixteen attributes), the similarity is

$$\mathrm{Sim}(6, Y, 16) = \frac{1}{\sqrt{0 + 1 + 1 + 1 + \ldots + (12 - 16)^2}}.$$

Based on this metric (selection criterion), a reduced number (nine here) of those cases are selected, the closest nine to the new case. This is done with the computer software ANGEL (analogy estimation tool, see either Shepperd, Schofield and Kitchenham (1996) or Shepperd and Schofield (1997) for further details). There is no particular reason for stopping selection at the number nine. In fact, it is possible to set a precision limit instead of fixing the number of cases to select. The values of the amount of learning (summative assessment) for the selected cases were 60, 65, 40, 40, 70, 60, 80, 30, 30 per cent.

Estimation of the amount of learning by EBA

The unknown amount of learning (of the new case) is estimated by a location statistic (mean, median) of those of the 'neighbour' cases, which in this case are the nine values obtained earlier. Here we use the median which was 60. The use of the median is motivated by two reasons: (i) data, as we are using here, exhibit generally skewed distributions (possibly caused by outliers). This in turn gives biased estimates, and the median is known to be affected less than the mean by this phenomenon, and (ii) the use of the median for inference purposes requires fewer assumptions than that of the mean.

Estimation of the the precision and validation

Bootstrap estimate of the standard deviation: In theory this is normally given by the standard error of the sample median, $s(x)$, i.e. using the distribution of the median which is not obvious.

The Bootstrap estimate of the standard error (calculated for the sample median) gives an easy and practical answer. A Minitab macro (BootstrapSE) was written to do the sampling and calculations. It then displays the median Bootstrap replications along with the sample median and its standard error Bootstrap estimate. The algorithm used for the macro BootstrapSE is given below.

Declare column variables x, y, md, mdt, $seboot$, med
Declare constant variables b, szx, i
Count x and store the result in szx
do $i = 1 : b$
sample szx elements from x with replacement and store them in y;
Find the median of y and store it in mdt.
let $md(i) = mdt(1)$
enddo
Find the standard deviation of md and store it inseboot.
Find the median of x and store it in med.
print md
print med, $seboot$
Plot the histogram of md

The execution of the macro BootstrapSE gave $s(x) = 60$ and $\widehat{\text{se}}_{\text{boot}}(s(x^*)) = 11.12$. How good is this estimate? For the answer we need to compare it to $\text{se}_{\widehat{F}}(\widehat{\theta}^*)$, which is obtained from the sampling distribution of $s(x^*)$

$$p_i = P\{s(x^*) = x_{(i)}\} = \sum_{j=0}^{4} \left[\text{Bi}\left(j; 9; \frac{i-1}{9}\right) - \text{Bi}\left(j; 9; \frac{i}{9}\right) \right].$$

The results are given in Table 2.

$x_{(i)}$	p_i
30	0.001449
30	0.028924
40	0.114473
40	0.220661
60	0.220661
65	0.114473
70	0.028924
80	0.001448

Table 2: The sampling distribution of the sample median.

The previous distribution gives $\mathrm{se}_{\widehat{F}}(\widehat{\theta}^*) = 11.08$ which is very close to the Bootstrap estimate obtained earlier. To have more insight into these estimates we constructed the histogram of the 200 replications used in the Bootstrap estimate and the histogram of 200 observations generated from the previous distribution (of $s(x^*)$). These turned out to be very similar (see Figure 3).

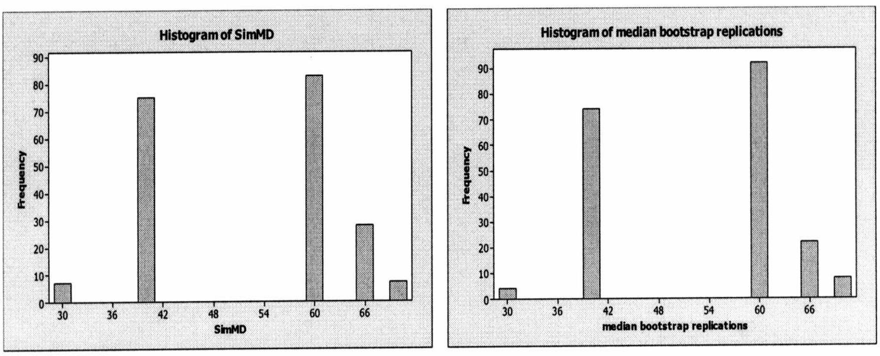

Figure 3: Simulated histogram, and Bootstrap histogram of the median distribution.

Bootstrap estimate of the bias and validation: The Bootstrap estimate of the median bias is used to estimate the bias of the sample median (which is 60 here as seen earlier). A Minitab macro (Bootstrapbias), with an algorithm similar to that of BootstrapSE, was written to do the sampling and calculations. It then displays the bias Bootstrap replications along with the sample median and its Bootstrap estimate of the bias $\widehat{\mathrm{bias}}_{\mathrm{boot}}(s(x^*))$. The execution of the macro Bootstrapbias gave $\widehat{\mathrm{bias}}_{\mathrm{boot}}(s(x^*)) = -4.9$ which is the Bootstrap estimate of the median bias. This negative value suggests that our sample median (of sixty) underestimates the actual median, and needs correction. A validation operation is needed. The corrected median is then,

$$s(x)_{\mathrm{cor}} = 60 - \widehat{\mathrm{bias}}_{\mathrm{boot}}(s(x^*)) = 60 - (-4.9) = 64.9.$$

So our estimate (prediction in fact) of the 'amount of learning' for the new section is $s(x)_{\mathrm{cor}} = 64.9$ per cent.

Advantages, limitations, and drawbacks

In addition to simplicity, this procedure has the advantage of requiring almost no theoretical background, and almost no assumptions about the data. As a prediction method, it gives a chance to the teacher or researcher to take corrective action over his or her teaching style based on the estimated value. But it is limited in the sense that it does not involve all aspects of learning, and is not applicable in the case of a new course programme since no history is available. The major drawbacks are that it does not involve the factors related to learning explicitly, and relies on values of the response variable recorded from historical cases which may be scarce.

Conclusion

This simple way of predicting such an abstract phenomenon as learning with validation action could be very helpful to parties involved with curriculum assessment. It represents, in particular, an attempt to employ reliable tools in the learning assessment process. It certainly has some drawbacks as mentioned above, but with more refinement, it could constitute a robust method to contribute to a more rational way of analysing such issues.

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Improving student performance using LanSchool broadcast

Sufian Abu-Rmaileh[1] and Khaled Hamdan[2]

[1] *English Department, University General Requirements Unit, United Arab Emirates University, Al Ain, United Arab Emirates*
[2] *Information and Communication Technology Department, University General Requirements Unit, United Arab Emirates University, Al Ain, United Arab Emirates*

Abstract

In this paper, we discuss how student classroom performance is improved using LanSchool broadcast software. We discuss how the sharing of ideas and responsibilities and time on task were helpful to our students. Finally, how students were evaluated during the process of using LanSchool and how responsibility towards one's learning shifted from teacher to the whole class will be addressed.

Introduction

Technology has triggered a huge social debate on whether it has helped people to improve their lives or made them lazy and unable to sue their own capabilities. Many consider technology to be a double-edged sword doing more harm than good. These people believe that it has had negative consequences on our way of thinking, our health and our environment.

In this paper, we only talk about the positive effects of technology. The discussion includes the impact of technology on communication, language, writing and education in general. We discuss the use of the LanSchool broadcast system in the classroom. We discuss its impact on student achievement based on test results taken from end of semester grade point averages.

The positive effects of technology

Technology has had a great effect on people all over the world. It has not only affected our behaviour, but also our way of thinking. Everyday there is something new to think about that enhances the use of technology. In *Critical issue: Using technology to improve student achievement*, it is stated that

> . . . along with expanded access has come a growing pervasiveness of technology in society. For a generation of young people, technology, particularly the Internet, has assumed a substantial stake in their social and educational lives. (North Central Regional Educational Laboratory, 2005, p. 1).

These inventions pamper, and support human activity in many ways. They affect personal comfort, choice, health and safety, movement and our environment. It has become something that we cannot live without.

In a recent article entitled *Technology that changed our lives*, it states that

> Technology is evolving at such a rapid pace it's hard to tell what will happen in six months. It's hard to predict what products will make it to the market and which will take the crown and end up as everybody's favourite toy, business companion or home entertainment device. (Softpedia News, 2005, p. 1).

Technology has enriched and simplified our lives. For example, nowadays you can download or view articles on the Internet in seconds. This was impossible just a few years ago. Whatever topic you can think of, you can be sure to find information on the World Wide Web. Information is now literally at the tips of your fingers. You can also reach people in different parts of the world from the luxury of your home using live chats and using messenger services.

Impact of technology on communication, language and writing

Technology has had a huge impact on communication. We can reach people in different parts of the world from our homes using live chats and messenger services. In addition, it has had a great impact on language teaching in the classroom. It supports teachers with various tools, generically known as computer assisted language learning (CALL). Software, like interactive dictionaries, self-correcting grammar exercises, listening and reading programmes and word processors help teach and improve the different language skills. The North Central Regional Educational Laboratory (NCREL) writes that

> [l]ikewise, in teaching language learners, using technology has distinct advantages that relate not only to language education but preparing students for today's information society. Computer technologies and the Internet are powerful tools for assisting language teaching because web technology is a part of today's social fabric, meaning language learners can now learn thorough writing e-mail and conducting online research (NCREL, 2005, p. 9).

Learning a new language is not the only thing that has changed. The social language of the world is also changing with computers. People are using a common language to communicate, network and socialise. It is important to remember that

> The present day changes in our social and cultural lifestyles are so much influenced by today's technological advances that it makes up a language

> much different than was spoken a hundred years ago. The technology effect has brought upon us a jargonified language within common speaks of life, which would be difficult to be understood by our ancestors (Technology Influence on Our Lives, 2005, p.1).

Computer jargon needs technologically savvy people to understand it. Words like G2G, LOL, Btw, gr8, tyt, etc., which mean respectively: got to go, laugh out loud, by the way, great, take your time, have evolved because of chatting on the Internet and the use of e-mail where people tend to modify their language so that they can manoeuvre swiftly.

Writing has been affected further. Coley (1997) states that

> Numerous studies have demonstrated that technology is particularly valuable in improving student writing. The ease with which students can edit their written work on word processors makes them more willing to do so, which in turn improves the quality of their writing (p. 1).

Students can create documents, hand them in to their teacher immediately, or send them in e-mails for editing. Students can also edit their own work with as many revisions as they want. They can also edit other students' work in less time, with ease and precision.

Students need a range of tools to grab their attention. They tend to bore easily. Teachers need to use alternate ways with varied tools to keep students on track.

> [S]tudents must have a range of skills to express themselves not only through paper and pencil, but also audio, video animation, design software as well as a host of new environments (e-mail, websites, message boards, blogs, streaming media, etc. (NCREL, 2005).

This means that all those tools and all that software should be at the disposal of the classroom teacher. It also means that students be well trained in using them.

Impact of technology on education

Education has been highly affected by technology. The way teachers use it in the classroom to help themselves teach their subject has changed. Technology is not only used for the sake of learning about technology, but also for the sake of learning itself (Richmond, 1997). It supports the whole curriculum. For example, a spreadsheet can be used for learning information technology as well as mathematics.

Nowadays, not only teachers, but also students have access to technology. Classrooms are wired with tools to ease both the learning and teaching process. They are wired to motivate students to use something that they think is cool. At the same time they learn how to do their homework and projects, and improve their knowledge and learning skills. Technology is making students more active learners as they connect with each other in the classroom, across the Internet and to a multitude of references and sources for research at all levels (ATTIC Brown Bag Lunch, 1997).

Besides the teacher, connecting with others, learning from others and teaching others are the new trends in the modern classroom. Moreover, technology in the classroom has the potential to help students improve their attitudes towards learning and to motivate them to do better. Richmond (1997) comments that 'many educators believe

that the new computer and communications-based technologies have much to offer K–12 education and that infusion of technology into school setting will bring profound changes' (p. 4). These changes are expected to be for the betterment of the students: their achievements and ability to stay on task.

Finally, one could also hope that with technology, students would be able to involve themselves more in the education process. They would become creators and owners of their work; something they could be proud of. Who would not be interested or active in a project that they can have a say in? Certainly, students who get involved in their own education would have a greater stake in what they are doing.

The use of LanSchool broadcast software

LanSchool is one classroom technological tool that enables teachers to broadcast whatever they want to the students. It enables teachers to give students access to other students' screens and work. It enables teachers to view student work from a remote computer. It also enables teachers and students to do many other functions that can help in the teaching and learning process. Kuhio Elementary School Local Area Network Plan (2005) states that

> . . . the LAN . . . will allow each classroom to be able to communicate with other classrooms in their own school as well as other schools. Students will use the technology as tools for learning rather than as ends in themselves (p.1).

Those tools support the learning process in general, creating better student-teacher communication and interaction.

In addition, Richmond (1997) states that

> effective use of software intended for direct instruction has been beneficial in many settings and for many specific uses when implemented by teachers who have a clear understanding of potential benefits and limitations of such learning resources. (p.2)

This understanding takes into consideration that one has to train those who use the software. With LanSchool broadcast, one can expect students to be able to use such a system after one or two classroom sessions. This is something worth doing for students so that they succeed and achieve well in the tasks at hand. Finally, we reiterate that a computer or any technological tool does not replace the teachers' role in advancing the teaching and learning process. Technology complements what teachers do in the classroom.

Impact of technology on student achievement

Coley (1997) points out that the

> effectiveness of educational technology shows that rudimentary uses of computers using drill and practice software, for instance, to teach addition and subtraction can be effective and efficient. (p. 1)

To prove this effectiveness, the authors conducted two separate investigations at the campus of the United Arab Emirates University. The first was in collaboration with the Information Technology teachers. This was called the Timed-Task Case Study.

The other was done by conducting a survey of how teachers used technology in general, and a LanSchool broadcast in particular, in the classroom, and the student perception of the two. At the beginning of the semester, the students were told that they would be working together in groups and that they would assume leading roles of their groups. They were also told that they would get the same mark for the job that they were doing using the LanSchool broadcast program. For that reason, questions 7, 10 and 11 of the survey covered the above points (see Appendix).

Timed tasks: Case study

For the timed tasks, sixteen sections were involved in the study. Each section had an average of eighteen students with a total of 280 students in all sections. Four teachers were involved in facilitating the work.

All sections were given a uniform university mid-term examination to see if there were any differences in students' averages and abilities. There were no noticeable differences in the averages between the researchers' students and students from other sections.

After the mid-term, the students were exposed to the LanSchool broadcast program used in the researchers' classrooms. Students were taught how to use the program. Then, the researchers' delivery of different lessons with LanSchool was done daily. After that, and under the direction of the researchers, the students picked up on this and started working in groups. After the exposure to using LanSchool, the students were given two tasks and a final examination.

The first timed task after the mid-term was designed by the researchers. It was given to the sixteen sections. The researchers' class average on this task was 88.6 per cent. Other teachers' sections scored an average of 81.8 per cent. This shows an improvement in the researchers' classes of 6.8 per cent over other sections (see Table 1).

	Main Teacher (%)	Average from all teachers (%)
Mid-term	82.8	81.9
Task 1	88.6	81.8
Task 2	88.6	86.4
Final Exam	70.7	66.7

Table 1: Times tasks and average test results.

To avoid bias, the second timed tasks after the mid-term was designed by another teacher involved in the study and not by the researchers. It was given to the 280 students in the study. The researchers' class average on this task was 88.6 per cent. Other teachers' sections scored an average of 86 per cent. This shows an achievement in the researchers' classes of 2.6 per cent over other sections.

For the final assessment, the students were given a uniform, university-designed final examination. Neither the researchers nor the other teachers were involved in designing or administering the final test. It was given to the sixteen sections. The researchers' class average on this examination was 70.7 per cent. Other teachers' class sections scored an average of 66.7. This shows an achievement in the researchers' classes of 4 per cent over other sections.

Technology survey

At the end of the first semester 2005, a total of 65 students from the University General Requirements Unit, IT programme (women's campus) were given the survey. Forty-two or 65 per cent responded. The survey had thirteen items (see Appendix). The results are discussed below.

Results and analysis

For question one, all respondents said they liked using technology in the classroom.

For question two, the most frequently selected item, at 40 per cent, was having better performance. Next came doing homework with 38 per cent. *Using better time management* was third, and fourth with 33 per cent. *Having strong relationships with peers* received 21 per cent (see Table 2).

	Frequency	Percentage
Having better performance	40	17
Doing team work	38	16
Using better time management	33	14
Having strong relationships relationships with peers	21	9
Completing tasks (assignment)	17	7
Having strong study habits	14	6
Being organised	14	6
Having motivation	12	5
Having responsibility	10	4
Being on task	7	3
Others	5	2

Table 2: Ways in which technology helps.

For question three, 79 per cent said that they had used LanSchool before; nineteen per cent said they had not. One student was neutral (see Table 3).

	Frequency	Percentage
Agree	33	79
Neutral	1	2
Disagree	8	19

Table 3: Have you used LanSchool broadcast program with your teachers?

In question four, 76.2 answered affirmatively (see Table 4).

	Frequency	Percentage
Agree	32	76.2
Disagree	10	23.8

Table 4: Have your teachers used LanSchool broadcast in your classroom?

For question five, 95.2 per cent said that LanSchool helped them in class. Two students gave no response (see Table 5).

	Frequency	Percentage
Yes	40	95.2
No Response	2	4.8

Table 5: Did a LanSchool broadcast program help you in class?

For question six, the most selected items were *doing teamwork* and *being on task*, selected by 19.1 per cent. The second highest was *using better time management* with 17.6 per cent; the third highest was *having strong study habits* at 10.3 per cent (see Table 6).

	Percentage
Having better performance	8
Doing team work	20
Using better time management	21
Completing tasks (assignment)	3
Having strong study habits	11
Being organised	6
Having motivation	8
Having responsibility	2
Being on task	21

Table 6: In what ways did the LanSchool broadcast program help?

For question seven, 76 per cent said that they liked to be team leaders. Seventeen per cent did not. Three respondents were neutral (see Table 7).

	Frequency	Percentage
Agree	32	76
Neutral	3	7
Disagree	7	17

Table 7: Do you like to be a leader in the classroom or a team leader showing your work to other students?

For question eight, 26.3 per cent said that they enjoyed using LanSchool. 57.9 per cent said they enjoyed it somewhat while 10.5 per cent did not enjoy the experience (see Table 8).

	Frequency	Percentage
Greatly		28
Somewhat		55
Not sure		6
Did not enjoy		11

Table 8: How much did you enjoy using a LanSchool broadcast program?

For question 9, 71.4 per cent said they liked working in groups with LanSchool; 23.8 per cent did not. The rest were neutral (see Table 9).

	Frequency	Percentage
Agree		71
Neutral		5
Disagree		24

Table 9: Did you like working in groups with LanSchool broadcast?

For question 10, 50 per cent thought that it was all right to use the same mark for the whole group; 45 per cent said that it was not. Five per cent were neutral (see Table 10).

	Frequency	Percentage
Agree	21	50
Neutral	2	5
Disagree	19	45

Table 10: Do you think it was fair to use one uniform grade for everyone in the group?

For question eleven, 55 per cent answered that they felt embarrassed when they did not answer correctly. Forty-five per cent said they did not (see Table 11).

	Frequency	Percentage
Agree	23	55
Disagree	19	45

Table 11: Do you feel embarrassed when you do not answer correctly?

For question 12, 24 per cent thought that using LanSchool forced them to study while 52 per cent said that it did not. Twenty-four per cent were neutral (see Table 12).

	Frequency	Percentage
Agree	10	24
Neutral	10	24
Disagree	22	52

Table 12: Does a LanSchool broadcast force you to study, knowing that your answers will be shown to others?

For question 13, *what other ways do you think can help you learn?*, students thought that having extra computers would. They also thought that having a learning guide would assist them in learning. Finally, they thought that having a preview of the material taught would be a great help.

Conclusion

From the above study, one can easily see how technology is affecting our lives as a community and as individuals. It is also affecting our classrooms and our students' behaviour. Clearly, teachers can benefit greatly from the technological tools that are put at their disposal. Without such tools, classrooms would lag behind what is offered elsewhere.

From the analysis of the use of LanSchool, the researchers found that student performance improved. They showed that students, when exposed to such a program, have a better chance of improving their marks on familiar tasks given to them by their teachers or other teachers. The researchers also found that students with such exposure could perform better on a uniform, university-designed and administered examination.

Students agreed that using technology and the LanSchool broadcast program helped them to study more, prepare better and ultimately perform better. With that idea in mind, both teachers and students could start reaping the rewards of technology in all subjects, not only in the IT classroom.

Appendix

Using Technology Questionnaire

Answer or Circle your answer for the following questions.

1. Do you like using technology in the classroom?

   □ Agree □ Disagree □ N/A

2. In what ways does it help?

   □ Improving performance
   □ Improving responsibility
   □ Doing team work
   □ Improving motivation – Active
   □ Completing tasks (assignment)
   □ Being on task
   □ Being organised
   □ Improving study habits
   □ Using better time management
   □ Improving relationships with peers
   □ Other

3. Have you used LanSchool broadcast program with your teachers?

   □ Agree □ Disagree □ N/A

4. Have your teachers used LanSchool broadcast programme in the classroom?

   □ Agree □ Disagree □ N/A

5. Did LanSchool broadcast program in class help you?

   □ Agree □ Disagree □ N/A

6. In what ways did a LanSchool broadcast program help you?

   □ Improved performance
   □ Improved responsibility
   □ Doing team work
   □ Improved motivation – Active
   □ Completing tasks (assignment)
   □ Being on task

- ☐ Being organised
- ☐ Improved study habits
- ☐ Using better time management
- ☐ Improved relationships with peers
- ☐ Other

7. Do you like to be a leader in the classroom or a team leader showing your work to other students?

   ☐ Agree ☐ Disagree ☐ N/A

8. How much did you enjoy using LanSchool broadcast program?

   - ☐ Greatly
   - ☐ Somewhat
   - ☐ Not sure
   - ☐ Didn't enjoy it

9. Did you like working in groups with LanSchool broadcast?

   ☐ Agree ☐ Disagree ☐ N/A

10. Do you think it is fair to use on uniform grade for everyone in the group?

    ☐ Agree ☐ Disagree ☐ N/A

11. Do you feel embarrassed when you did not answer correctly?

    ☐ Agree ☐ Disagree ☐ N/A

12. Does a LanSchool broadcast force you to study knowing that your answers will be shown to others?

    ☐ Agree ☐ Disagree ☐ N/A

13. What other ways do you think can help your learn?

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General

An innovative, constructivist approach to encourage more independent learning in and out of the classroom

F. Sanaa

IT Department, University General Requirements Unit, United Arab Emirates University, Al Ain, United Arab Emirates

Abstract

This research is based on the question, how can students come to class better prepared? My students usually come to class knowing nothing about the lesson because they have not read their textbook or any other related material prior to class. Many even come without textbooks or notebooks. This study compared an innovative constructivist method and a traditional teaching method. Improvement in marks on quizzes and examinations showed that the constructivist approach helped students become more engaged in and responsible for their learning both in and out of the classroom.

Introduction

Students usually come to class to discover the new lesson to be explained by their teacher. Most, if not all, do not read the textbook or any other material related to the lesson. Many even come to class without notebooks or textbooks. Students wait for examinations before opening their books to figure out which chapters have been covered. Coming to class prepared includes bringing the required materials such as notebooks, textbooks, and any necessary worksheets as well as reading beforehand the lessons that will be covered in the class. This helps learners build their knowledge and understanding of course concepts.

What is action research (Classroom research)

Action research, or classroom research, involves systematic and planned critical reflection on pedagogical practices in the classroom, assessment of whether goals were achieved, and identification of what has or has not gone well. The results are shared with others. Action research entails identifying a problem or area needing improvement, by focusing on issues that are manageable and have an immediate, practical application, and finally formulating an hypothesis about the possible source of the problem or issue (McKeachie, 2002).

The teacher sets up an ‘experiment’ by planning an intervention, a change from the current practice, and decides on an appropriate data collection system to determine how the experiment is to work. The teacher conducts the experiment and collects data. Analysing the data allows the teacher to discover whether the experiment has worked. In other words, have things changed or improved? What has been the outcome? The teacher then shares what was learnt with others. However, this is not the end. At this point teachers involved in action research ask themselves: could we do anything differently, what would be the next logical step, how will we know if we have been successful? This is the never-ending spiral of action research and reflective teaching (Cross and Steadman, 1996).

Action research is a valuable tool because it is directly connected to what is happening in the classroom. It helps teachers become more aware of and open to problem solving. Teachers’ attitudes, skill and knowledge are positively affected as they engage in research that will have immediate and practical effects upon their classrooms (Mills, 2000).

A constructivist approach to learning

Researchers have moved from viewing the teacher as belonging at the centre of the learning process, to viewing the student as having a more central and active role. This student-centred approach is sometimes referred to as constructivism because it sees students as constructing their own understanding (Davis, 1997). What does it mean to place students at the centre of the learning process? In one sense, it means teachers’ jobs are more demanding because it is often more difficult to make student-centred approaches work than it is simply to stand at the front of the room and give a lecture. The classroom climate should be challenging but not threatening to students (Caine and Caine, 1991).

Constructivist approaches require thorough planning, tools and equipment, and in-depth knowledge of the students. Student-centred teaching has been the foundation of so-called ‘open schools’, a term often used to describe schools in which students are actively involved in deciding what and how they will study (Pintrich and Schunk, 1996).

With the constructivist perspective comes an increased awareness of individual differences in the classroom and a renewed emphasis on the role of prior experiences and learning (Sternberg and Williams, 2002). Schulte (1996) maintained that, in constructivist learning environments, students come to the classroom equipped with their personal experiences, and cognitive and affective skills, which all have a remarkable influence on their perspectives about how things operate in the real world

A comparison between a constructivist and traditional classroom

In a traditional classroom, students wait for the teacher to explain lessons with reference to their textbooks. Students are passive receivers who learn what the teacher tells them to learn in the way they are told to learn it (Schulte, 1996). They are then assigned different exercises and homework to reinforce the learning. The job of the teacher as an educator is to concentrate on how to teach and what to evaluate. As a result, students

strive only to complete the activity quickly and correctly with little though of the task's significance (Schulte, 1996). The teacher measures observable behaviour rather than conceptual change or understanding. The result is that students memorise a variety of terms, but often cannot apply them to problems or outside experiences because they do not truly understand them (Schulte, 1996).

Constructivism recognises that students have different levels of understanding and thus it presents a variety of ideas. Students can then share their understanding with their peers for clarification. Students may not be thinking in the same manner, but they are learning in ways that are meaningful to them. No longer is the teacher seen as an expert who knows the answers to the question she or he has constructed. The students are asked to identify their teacher's constructions rather than construct their own meanings.

In a constructivist classroom, students are encouraged to use prior experiences to help them form and reform interpretations (Gray, 1997). Textbooks are a part of the constructivist classroom as long as the teacher does not completely rely on them for meaningful learning and students clearly understand the purpose of reading (Schulte, 1996). They start from there, construct their own reading strategies and then build their learning.

Method

Sampling

From the four Information and Communication Technology first level (ICT1) sections I taught in the autumn semester of 2005, the research was applied to only two sections (section 814 and 810). The other two sections used traditional teaching methodologies (section 601 and 813).

Procedure

Before each new lecture, students were asked to come to class prepared. The preparation included reading the chapters to be covered in the class beforehand in order to have a basic idea about the lesson and its level of difficulty and bringing the necessary materials to class such as notebooks and textbooks.

Materials used for the research

To do the evaluation, two types of material were prepared and distributed to students. These were (i) weekly assignments, (ii) and four quizzes to evaluate student understanding.

Distribution of the assignments

The weekly assignments were distributed in the same way to all four sections, the experimental group (evaluated sections) and the control group (non-evaluated sections), but additional instructions were given to the experimental group.

- Experimental group: Students were asked to read the chapter for the next session. To verify that the students had done their homework in the correct way, the following specific tasks were assigned: (i) writing new keywords that require understanding and summarisation in their notebooks, and (ii) preparing at least one question from all lessons read in the chapter. The teacher also sent an e-mail to all the students describing the homework in detail.

- Control group: Students were asked to read the chapter for the next session and concentrate on the lessons that require memorisation.

The teacher's classroom task with a completed assignment

- Experimental group
  - Verifying notebooks: The teacher collected student notebooks, checked the keywords and questions and provided individual feedback on the quality of the work based on organisation, relevance and presentation.
  - Opening a discussion: The teacher asked the students about the prepared chapter's level of difficulty, the problems they faced doing their assignment, and reading strategies used to understand the chapter.
  - Explaining the new chapter: The teacher explained the new chapter, answered all student questions written in their notebooks, and referred students to their notebooks to complete keyword lists and answers to questions.
  - Distributing the quiz: To test understanding, during the last fifteen minutes, the teacher distributed a theoretical quiz that summarised the most important points of the lesson.
- Control group:
  - Explanation of the new chapter: The teacher explained the new chapter and answered student questions.
  - Distributing the quiz: To test understanding, during the last fifteen minutes, the teacher distributed a theoretical quiz that summarised the most important points of the lesson.

Returning corrected assignments

- Control group: The teacher returned the marked quizzes and provided students with correct answers.
- Experimental group: The teacher returned marked assignments, pointed out the students who got full marks and discussed with the class the learning and reading strategies they applied. The teacher wrote the different strategies on the board and encouraged other students to use them to improve their marks in the coming quizzes. The teacher then provided answers to the questions in the quiz.

Summary of student feedback

- Reading strategies used.
  - Reading the lesson before coming to the class.
  - Skimming the paragraphs carefully.
  - Underlining or highlighting important parts of the lesson.

  - Identifying keywords (bolded words).
  - Translating or explaining difficult words.
  - Constructing a vocabulary list in notebooks.
  - Organising notebooks.
  - Identifying main ideas from lessons.
  - Read more than once.
  - Preparing questions about the points that are not clear.

- Learning strategies.
  - Paying attention to the teacher's explanation in the class to reinforce understanding of the lessons.
  - Listening carefully.
  - Completing the vocabulary list in notebooks.
  - Asking questions.
  - Completing all practice tasks in class.
  - Sharing duties in group work activities.

Results

Student performance on evaluation quizzes

- Experimental Group
  - Section 814: Figure 1 shows that the average score steadily increased except for the last quiz which went down to four. However, 60 per cent scored full marks.
  - Section 810: Figure 1 shows that the average score increased over the last three quizzes. In quiz four, 50 per cent scored full marks.

This clearly shows that students benefited from the constructivist method as they became more serious about coming to class prepared.

- Control Group. For both sections, there was no clear improvement as marks varied up and down from one quiz to another.
  - Section 813: Only 33 per cent scored full marks.
  - Section 601: Only 13 per cent scored full marks.

The teacher had no way to verify whether the students did any reading before coming to class. The students did not take the method seriously, so their quiz scores went up and down. They relied completely on the teacher's explanation in class. This was not enough to improve their marks.

The timed tasks assigned in the classroom were all practical. They were based on scenarios and tasks for students to do. Students were then required to do some reading

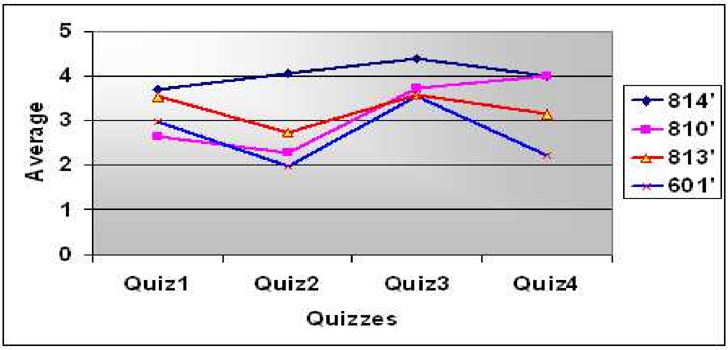

Figure 1: Comparison of evaluation quiz averages for each section.

to understand what they were supposed to do. Students in the experimental groups developed their own reading strategies and applied them in the assigned timed tasks. Therefore, their marks were higher and they improved from one timed task to another.

Figure 2 clearly shows that students in both experimental groups improved their marks, whereas there was very little improvement in section 813 and a decline in section 601 (control groups).

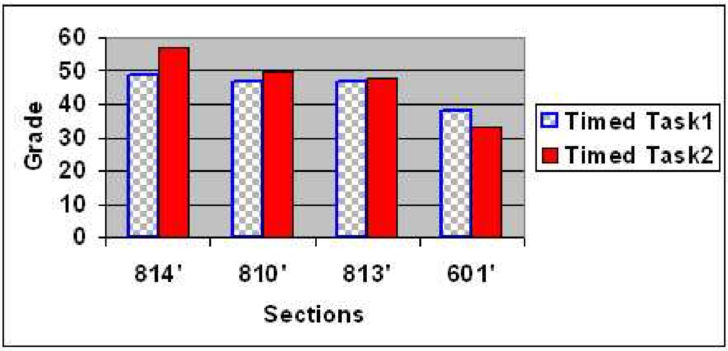

Figure 2: Comparison of class timed tasks averages for each section.

Student performance on the mid-term examination

The mid-term examination was based on scenarios and tasks where the students had to read each scenario carefully to be able to select the correct answer and then do the associated tasks. This required students to use reading strategies such as identifying keywords and highlighting them, translating or explaining the difficult words and then deciding which software to use.

Figure 3 clearly shows that the average in the mid-term examination is higher in the sections where the constructivist approach to teaching was applied. Even though the level of students in section 813 (control group) is much better than section 810 (experimental group), the students in section 810 benefited from the constructivist method and performed well in the mid-term examination.

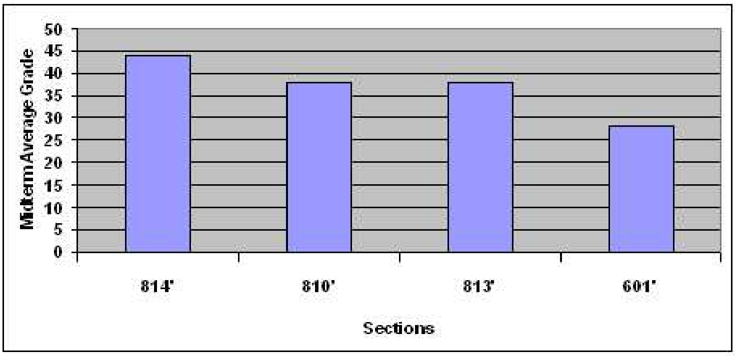

Figure 3: Comparison of mid-term examination averages for each section.

Conclusion

Since constructivism recognises that students are at different levels of understanding and presents a variety of ideas, teachers should start encouraging more student-centred learning in their teaching methodologies. The research presented shows that the constructivist method applied had a good effect on students' marks in comparison with the traditional teaching method. Therefore, more importance should be given to developing new methods to help students construct their own reading and learning strategies. Teachers should also devote time to preparing the material to be covered before the class, creating open discussions for students to share their strategies and ideas with their peers in the classroom, and encouraging students to use these strategies in courses other than IT. This will also help students seek out other resources such as textbooks and the Internet to localise their lessons and prepare themselves in their own time. In the end, students will become more responsible for their own learning than before, both inside and outside the classroom.

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It's not just about different chromosomes: On the differentiation of learning styles between males and females and implications for improving teacher protocols

B. Leanderson

Expressive Arts Department, Emirates National School, Abu Dhabi, United Arab Emirates

Abstract

Teachers have the capacity to become great facilitators of both male and female student learning. There are distinct differences in developmental, hormonal and cognitive areas which affect the learning process. The brain functions in different ways in males and females and these differences impact on learning, social development, and future career choices. We should recognise that developmentally, males mature at a slower rate than females. We also need to understand that male and female hormones have a direct impact, not only on physical and social development, but on the capacity to learn and feel safe in a learning environment as students advance from early puberty through teenage years to early adulthood. We have an obligation to better understand those differences in learning styles, behaviours and attitudes if we hope to become true mentors and role models for these students within the classroom as well as the community. Some of these differences and their implications on teaching will be explored in this paper.

Introduction

Research into brain activity has been enhanced greatly by PET[1] and MRI[2] scans since they provide us with detailed information about the way brains are 'hardwired'. Many of these studies show that males and females develop and process information differently. Males have less serotonin – which controls the ability to control oneself. Females have more oxytocin – a hormone linked to the instinct to bond with others. They tend to bond and work well in clusters in situations where collaboration is more valued than competition. The higher testosterone level in males is evidenced in behaviours that teachers are all too familiar with; they are more active, fidgety, restless, more competitive and aggressive. Females are calmer and pacifist in their natures. Males develop fine motor skills more slowly and their gross motor skills more rapidly than females, while their reading levels are lower than those of females of the same age. The frontal

[1]Positron Emission Tomography.
[2]Magnetic Resonance Imaging.

lobe is more active in females, which enables them to develop language skills earlier than males. Their verbal centres are more developed and they exhibit greater sensory detail. Males see the 'big picture' while females see detail. Males have more difficulty hearing lower volume speech than females and they tend to speak more loudly (Tyre, 2005; Goff, 2005). Girls will use many areas of the brain simultaneously to solve a problem while males tend to use far fewer areas for the same problem. Girls' brains are more ready to multi-task, integrate, corroborate, connect and communicate while male brains streamline, zero in on information, and ignore other items, focusing only on the information at hand (Deak, 1998). Emotional needs are dealt with differently as boys use the amygdala while girls use the cerebral cortex as the female amygdala produces more intense emotions than those of males. 'Grab a female's amygdala and her cerebral cortex will follow you anywhere' (Deak, 2002). Females have a more developed sense of smell, are more sensitive to touch and have more difficulty tuning out extraneous noise (Owens, 2003). All these differences mean that teachers need to accommodate these tendencies and provide learning situations where each gender has the opportunity for optimum learning and understanding of concepts to enable greater growth of skills.

The differences in learning styles and student behaviours have many implications for classroom management. As we proceed, we will come face to face with the reality that we might need to be altering what we do, where and when we do it, how and why we do it, and with whom we request that it be done.

Towards quality learning

Many studies agree that male students usually receive more attention from all teachers, be it positive or negative, in answering a question or in attention-getting behaviour. They also tend to dominate discussions in mixed gender classrooms, regardless of the gender of the teacher (Krupnick, 1985; Center for Teaching and Learning, University of North Carolina at Chapel Hill (CTL), 1997; Bell, 2002; Gray, 2001).

1. At the beginning of the course, provide opportunities for all to talk briefly to the whole class or in small groups. Assign roles for co-operative learning to group members so that all are responsible for some verbalisation. Possible choices are: timekeeper, recorder, peace-maker, and reporter. Get them all to play their roles within these groups.

2. Teachers should discuss the expectations for active participation early and often so that no one person or group dominates class discussion. Encourage active listening where all are focusing on the speaker and where students should be able to rephrase the previous speaker's statements prior to either adding to them or refuting them.

3. Request that a hand must be raised and that the student has to wait until it is acknowledged to speak; interruptions are unacceptable.

4. Observe students' non-verbal body language and invite answers from those who appear hesitant (they usually are signalling agreement by head nods or smiles).

5. Explain and consistently use wait time anywhere between three to five seconds after the question is posed.

6. Suggest that there be written answers from time to time instead of immediate class discussion. Students can 'think and write' instead of speaking or you can pair students with each other and have them do a 'think, pair, share' exercise prior to opening up a class discussion.

Teachers tend to give more eye contact, precise comments, and responses to boys. They also give more encouragement through non-verbal cues such as head nodding, leaning forward expectantly and smiling (CTL, 1997; Krupnick, 1985).

1. After a question is raised, look around the room and make eye contact with all. It will invite and encourage student participation regardless of gender (CTL, 1997).

2. Promote questions from either gender by asking follow-up questions or rephrasing the question while scanning the entire room.

3. Move about the room as you wait for responses and gently touch a shoulder in passing as you clarify, rephrase or give more details to encourage a response.

4. Again, use 'wait time' to your advantage as you move about, clarify or rephrase.

5. Instead of a verbal answer, students could be told to jot it down. Then the teacher could collect them and discuss them. Make sure that you attribute ALL answers to the person by naming that individual (Krupnick, 1985).

6. Give equal time to each gender. After a male response, follow with a female response. Girls will become more involved and participate more fully if given the okay to continue, be it verbal or non-verbal, by direct question or clarification.

7. Encourage students to follow up on remarks and extend them, not only to criticise or object.

8. Use frequent and brief feedback (smile, nod, yes).

Varying the structure of the class or revising the curricula to provide for different learning styles, participation, and collaboration is advantageous for both genders, but more so for females. Consider that:

1. Females are more comfortable collaborating within a group than males, who are much more competitive. Provide opportunities for both 'report and rapport'.

2. Males will use a different linguistic style answering directly. Females seek consensus and actively seek other people's opinions and ideas. They will preface remarks with 'I think', 'It may be that…', will qualify statements by adding 'maybe, perhaps', will apologize, 'I may be wrong but…', will use intonation that implies a question instead of an answer because they seek approval or will add tag questions, e.g., '…isn't it?'

Take these tendencies into consideration when organising and structuring learning and provide for both individual (competitive) and group (collaborative) activities. Make allowances for both 'report and rapport' learning. Be mindful of the different ways

that males and females respond and provide each gender equal time in responding to questions or entering a discussion.

Females can handle the increased focus on a practical application of a skill if given the time to develop it in a friendly, supportive group situation, especially in a science laboratory where unfamiliar equipment needs to be used properly for safety reasons and especially when the user is a novice. Furthermore, females have less tendency to demand that they 'take all the credit' for something and are pleased when they and their partners in collaboration receive recognition. So give praise where it is due and give it often (CTL, 1997).

Girls feel safer, have greater self-esteem, are more self-confident, and are willing to take more intellectual risks when in a single gender classroom. (Krupnick, 1985; Targan, 1996; Deak, 1998; Sax, 2005).

1. Females will talk less in a mixed gender group; males dominate conversations, call out answers and compete for time and space. We need to provide opportunities for balance when calling on students, i.e., alternate genders when acknowledging a raised hand.

2. Females will talk more in a single gender classroom with a female teacher. A female teacher is perceived as less threatening. Male teachers can mitigate this by encouraging diverse responses or follow-up statements, giving frequent and brief feedback, encouraging extension of responses by nodding, smiling, leaning forward, and in general showing interest in what that student has to say.

3. Interruptions occur more frequently in a mixed gender class, and once interrupted, many females do not demand 'equal time' to finish their statement or train of thought. They clam up. Make sure that you provide opportunities for continuation of the thought by restating the response and encouraging the female to continue her response. Seek collaboration from other female students before calling on a male.

4. Females are comfortable using a rotating style of participation where all get to say their piece, to add on to ideas or expand on them. Encourage this.

5. Males, if in a male only group, will tend to be louder, more boisterous, and use personal anecdotes to try to 'one-up each other'. Some ways to reduce this include:

   – to have 'answer chits'. Here each student must respond to one question and hand in his chit before anyone can answer a second question;

   – to have answers written down and collected, then read by the teacher who could then lead a discussion.

6. Much class discussion is biased towards those who assert themselves, have quick response times and are usually males. Therefore:

   – use and enforce waiting time;

   – do not give in to interruptions;

– insist that the student has to rephrase the previous statement before continuing on with own input (American Association of University Women (AAUW), 1992).

Educators can also assist female students in developing self-esteem, confidence, and social development by:

1. Encouraging administrators to seek balance with respect to the number of females and males in each class.

2. Providing as many opportunities for collaboration as for competition.

3. Encouraging the continuation of responses after any interruption and calling on females to talk when a male starts to dominate the discussion. Ask a number of females, rhetorically, 'What do you all... (name some females)... think?' This is less threatening than singling out one girl.

4. Providing an environment where they can develop leadership roles, take risks and meet challenges. Collaborative groups are an excellent method (Gray, 2001).

If you are able to create single gender classrooms, then do so, as that environment is extremely advantageous for females, especially in subjects where historically they have been in the minority, i.e., sciences, mathematics, engineering, medicine, and law. Females will be more likely to raise their hands and provide responses in a single gender class. They will not be as afraid to ask questions that clarify or limit the scope of an investigation. Give students lots of time to acquaint themselves with equipment (laboratory apparatus, mechanical or technical equipment) and practice hands-on skills necessary in your course, especially in a laboratory science course. They may have been short-changed in previous years, unwittingly, by another teacher. Females will be more open to critique and be more responsive to feedback, positive or negative, and will be more likely to have their responses credited, developed or adopted (Sax, 2005).

Research conducted and compiled by female science students, female lecturers and female staff through the New England Consortium for Undergraduate Science Education provides a wide-ranging list of teacher practices or protocols, which summarise what 'good teaching' is (Targan, 1996). The study's conclusion lists the following recommendations that all teachers can embrace:

1. Introduce, demonstrate, and have students use technical or mechanical equipment prior to the time a specific assignment requires the use of it.

2. Provide time for observing experiments and discussing results so students feel more comfortable using the required instruments.

3. Use gender neutral language in discussion.

4. Provide information on what the next lesson will cover prior to dismissal and pose a question that will start the next class. This provides students with the time to think and reflect.

5. Be approachable and friendly; show interest in the student.

6. Encourage study groups or require group work as a percentage of the course.

7. Use writing as a tool for understanding. Use think-pair-share exercises; collect them and provide written feedback.

8. Mark using rubrics with competencies. This works well with discovery oriented projects.

9. Give take home examinations. This reduces anxiety and the pressure of a time constraint.

10. Use a mix of question types, i.e., multiple choice, true/false, fill in the blank, short essay, so that as many learning styles as possible are covered.

All of the above are just good teaching techniques that are proven to work for all students.

Many educators are unaware that they treat the sexes differently in classroom settings. The Center for Teaching and Learning at the University of North Carolina at Chapel Hill's study, *Teaching for inclusion* (CTL, 1997) determined that:

1. If males are loud and offer differing opinions, defend their positions and compete fiercely, we say they are assertive. Yet, when females sometimes exhibit these same character traits, they are considered aggressive or abrasive.

2. Some teachers have a tendency to call on male students before females, give males more time to formulate answers, give more feedback and encourage them to extend their answers using higher order skills of analysis, synthesis, and evaluation, while asking girls questions that require a recital of facts.

3. We sometimes call on male students even when female students raise their hands or when no one does.

4. We often remember male names more easily, use them to attribute correct answers, and accept their interruptions while chastising females for the same infraction.

This same study recommends that we start using more strategies that will mitigate female students' tendencies to have lower confidence levels, such as:

1. Examine your own classroom behaviour. Ask a colleague to monitor certain behaviours you or students exhibit. Videotape a class or give students a checklist to fill out that lists whatever attributes you are examining in classroom management.

2. Note where students choose to sit. Are they at the back of the room? Are same-sex students in clusters or mixing with the opposite sex?

3. Speak, giving eye contact, feedback and praise to all.

4. Monitor what goes on in the room, especially during collaborative project discussion and research sessions.

5. Move around the room to be closer to all students.

6. Challenge all to elaborate on answers by giving an encouraging gesture or asking other leading questions.

7. Examine the curriculum to see if it is truly user-friendly to both sexes.

8. Try to adjust the report versus rapport ratio of male and female responses seeking:

   – either to state facts (usually a male tendency to zero in directly on an answer) or share experiences (female tendency towards inclusiveness and collaboration);

   – to raise oneself up one more rung of the ladder (male) or gain consensus and acceptance (female);

   – to compete versus collaborate.

Conclusion

Good teachers can become better; better teachers can become facilitators; facilitators can become inspirational. We all have the potential to provide excellence in education for both male and female students if we remember to:

1. Establish a professional atmosphere that is welcoming.

2. Expect no less from females than males and tell them they are capable of equal work.

3. Include study topics that feature women if applicable and appropriate (e.g. Mme Curie).

4. Provide real-life settings and examples for concepts studied.

5. Avoid bias and sexist language.

6. Listen to all responses with equal seriousness.

7. Challenge answers when appropriate.

8. Correct or praise when either is due.

9. Learn all students names and use them frequently.

10. Ask questions of equal difficulty to both genders.

11. Sequence responses between genders to reduce domination of discussions.

12. Take steps to prevent interruptions.

13. Intervene when necessary when comments of others occur and disrupt.

14. Permit students to complete their contributions to a discussion.

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